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THE PACES OF THE HORSE.[1]

IN the November MONTHLY we gave a brief account of Prof. Marey's method of representing the step of animals by means of graphic illustrations, with its application to human locomotion; we will now consider it as applied to the more complex paces of the horse. Hitherto, the locomotion of the horse has been mainly studied by means of the eye and ear. In the horse, even at a walk, the motions of the limbs are so confusing as to make it difficult for the untrained eye to follow them, and, when the pace is more rapid, the movements seem hopelessly intricate. Indeed, observation by the eye alone long since gave place to the use of the ear, which, taking account of the rhythm of the steps by the sounds they produce, afforded much more accurate results.

An expedient which greatly aided the observer, and which we shall find of service in explaining the results obtained by the graphic method, was to concentrate the attention on a single pair of limbs, instead of attempting to keep all four under observation at once. Any two limbs thus selected are called a *biped*, and this is designated according to the relative position of the limbs chosen. The horse may thus be parceled out into six different bipeds. The forward limbs constitute the *anterior biped;* the hind-limbs, the *posterior biped;* the two right limbs, the *right lateral biped;* the two left limbs, the *left lateral biped;* the right fore-leg and the left hind-leg, the *right diagonal biped;* the left fore-leg and the right hind-leg, the *left diagonal biped.* The horsey reader may dwell a moment upon this bit of equine technics, as it will materially assist him in understanding the explanation of the various paces.

The quadruped, when walking, has been compared to two men, placed one before the other, the hindmost following close upon the forward step of his companion. According as these persons (who ought both to take the same number of steps) move their limbs simultaneously, or alternately, according as the man in front executes his

[1] Abstract of Chapters IV., V., and VI., of "Animal Mechanism," by Prof. Marey. (Vol. XI. of "The International Scientific Series.")

movements more quickly or more slowly than the one behind, we see reproduced all the rhythms of the movements which characterize the different paces of the horse. Many have seen in the circus the figures of animals whose legs are formed by those of two men, with their bodies concealed in what represents the body of the quadruped. This grotesque imitation bears a striking resemblance to the animal when the movements of the two men are so well coördinated as to reproduce the rhythms of the paces.

Assuming the horse to be composed of two bipeds walking one be-

FIG. 1.—NOTATION OF A HORSE'S AMBLE.

hind the other, let these, in progressing steadily, go through the same movements at the same time; that is, let the right leg of each be advanced at the same time and rate, the feet striking the ground so as to give but a single sound. While the body is resting on these, the left legs are simultaneously thrown forward, each striking the ground at the same moment, and so on alternately. The pace thus produced is known as the *amble*, and is the simplest of all the paces of the horse. The notation of its rhythms is given in Fig. 1. The upper line is derived from the movements of the *anterior*, or foremost biped; the

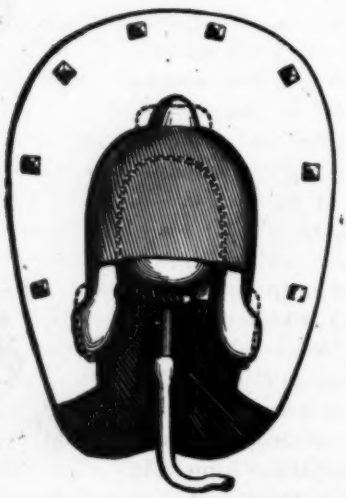

FIG. 2.—EXPERIMENTAL APPARATUS TO SHOW THE PRESSURE OF THE HORSE'S HOOF ON THE GROUND.

lower, from the movements of the *posterior* or hindmost biped. The foot-falls of the right and left foot being produced at the same time by the biped walking in front, and by the one which follows, must be

represented by similar signs placed exactly over each other. In the horse, this agreement between the movements of the fore and hind limbs belongs to the amble, and the notation is the same as would be given by that pace. In the amble, the ear perceives only two beats at each pace, the two limbs on the same side striking the ground at the same instant. In the notation, these two sounds are marked by vertical lines joining the two synchronous impacts. In the amble, the pressure of the body on the ground is said to be *lateral*, as the two limbs on one side only are in contact with the ground at the same time.

The rhythms of both the walk and the trot have been similarly ascertained and expressed, but beyond this the unaided senses have failed to give us much trustworthy information. It has been reserved for M. Marey to surmount the difficulties of the investigation; and we will now give, though necessarily in an imperfect way, some account of his methods and results.

For the shoe employed in the experiments on man, M. Marey substitutes, in the case of the horse, a ball of India-rubber filled with horse-hair, and attached to the shoe on the under-side of the hoof. The contrivance is shown in Fig. 2. A strong band of India-rubber passes over the apparatus and keeps in its place the ball filled with horse-hair, allowing it to rise slightly above the lower surface of the shoe. When the foot strikes the ground, the ball is compressed, which drives a part of the confined air into the registering instruments. As the foot is raised the ball recovers its form, and again fills with air, to be expelled at the next impact of the foot on the ground. Another form of apparatus, serving substantially the same purpose, and better adapted to ordinary roads, is seen in Fig. 3. This consists of a kind of leather bracelet fastened by straps to the leg of the horse just above the fetlock-joint. In front of this bracelet, which furnishes a solid point of resistance, is firmly fixed a flat box of India-rubber; this box communicates by a transmission-tube with the registering apparatus. Every pressure exerted on the box moves the corresponding registering-lever. A plate of copper,

FIG. 3.—APPARATUS TO GIVE THE SIGNALS OF THE PRESSURE AND RISE OF THE HORSE'S HOOF.

inclined about 45°, is connected at its upper extremity with a kind of hinge, while its lower end is fastened by a heavy wire to the upper face of the India-rubber box, on which it presses by means of a flat disk. On a wire parallel to the slip of copper slides a ball of lead, the position of which can be varied so as to increase or diminish the pressure which this jointed apparatus exerts on the India-rubber box. This apparatus is called into action by the movements of the limb; the inclination of the oscillating portions allows them to act on the membrane constituting the wall of the box during the movement of elevation, of descent, and of horizontal progress of the foot.

The general arrangement of the apparatus, as it is applied to the horse, is seen in Fig. 4. Thick transmitting-tubes, not easily crushed, connect the experimental shoes, or instruments, on the legs, with the

FIG. 4.—THIS FIGURE REPRESENTS A TROTTING-HORSE, FURNISHED WITH THE DIFFERENT EXPERIMENTAL INSTRUMENTS; the horseman carrying the register of the pace.—On the withers and the croup are instruments to show the reactions.

registering apparatus in the hand of the rider. The registrar now carries a great number of levers; he must have four, at least, one for each of the legs, and usually two others, which receive their movements of reaction from the withers and the croup. The hand which holds the reins also carries a ball of India-rubber, which is connected by a tube with the registering instrument, and by means of which the tracings may be made to commence at any desired moment.

The tracings furnished by this apparatus, when the horse is at a full trot, and the notation of the rhythm of that pace, as derived from these tracings, are shown in Fig. 5. Above are the reactions taken from the withers for the fore-part of the animal, indicated by the line *R A* (anterior reactions), and from the croup for the hinder part, indicated by the line *R P* (posterior reactions). Below are given the

curves of pressure of the four feet, drawn at two different levels: the uppermost are the curves of the anterior limbs; those below, of the posterior limbs. In each series the curves of the left foot are drawn with dotted lines, those of the right with full lines.

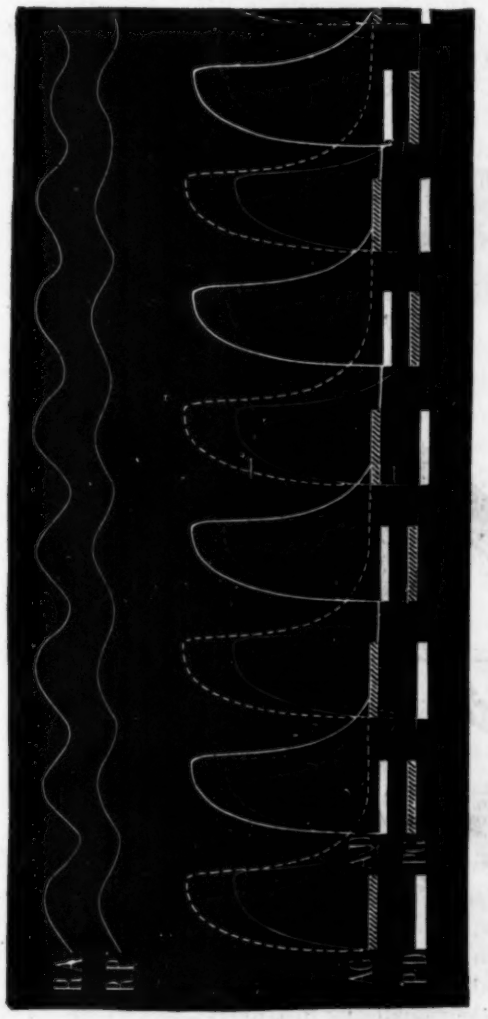

FIG. 5.—GRAPHIC CURVES AND NOTATION OF THE HORSE'S TROT.—*R A*, reactions of the fore-limbs; *R P*, reactions of the hind-limbs; *A G* and *A D*, curves and notations of fore-limbs; *P D* and *P G*, curves and notations of hind-limbs.

The moment when the curve begins its rise represents the commencement of the pressure of the foot on the ground; the point at which the curve begins to descend represents the moment when the rise of the foot commences. It is seen from these tracings that the feet *A G* and *P D*, left fore-foot and right hind-foot, strike the ground at the same time. The simultaneous lowering of the curves of the two feet shows that they also rise from the ground simultaneously.

Under these curves is placed the notation which represents the pressure of the left diagonal biped. The second impact is given by the feet *A D* and *P G* (right diagonal biped), and so on through the whole length of the tracing. Thus the free trot is a pace in which all the four feet give but two strokes, and in which the ground is struck in turn by the two diagonal bipeds; it is also a *high pace*, the animal being raised for a brief interval between two successive strokes above the ground. The duration of this suspension, according to Fig. 5, is equal to half the time the feet are pressing on the ground. But the

FIG. 6.—NOTATION OF THE IRREGULAR TROT.

trot varies greatly in different horses in this particular, there being oftentimes a very slight period of suspension, although a perfect synchronism of the diagonal strokes of the feet is observed.

By comparing the lines illustrating the reactions with the tracings afforded by the movements of the limbs, it will be seen that the mo-

FIG. 7.—HORSE TROTTING WITH A LOW KIND OF PACE.—The instant corresponding with the attitude represented in this figure is marked with a white dot on the notation.

ment when the body of the animal is at the lowest part of its vertical oscillation coincides precisely with that at which its feet touch the ground. The time of suspension does not depend on the fact that the

body of the horse is projected into the air, but upon the fact that all four legs are bent during this short period. The maximum height of the suspension of the body corresponds, on the contrary, with the end of the pressure of the limbs on the ground. It is also seen that the reactions of the fore-limbs exceed those of the hind ones. This inequality appears to be constant, and is still more marked in the walking-pace.

We have learned that one of the chief characteristics of the free trot is the entire synchronism of the strokes of each diagonal biped. There is a form of this pace, however, called by M. Marey the *irregular trot*, where such synchronism is wanting, the hind limb of one or both diagonal bipeds striking the ground an instant later than the corresponding fore-limb. Fig. 6 represents the notation of the irregular trot. The stroke of the left fore-foot is seen to be a little earlier than that of the right hind-foot, and the same is true of the limbs belonging to the right diagonal biped.

The *low and short trot* is represented in Fig. 7. The diagonal impacts succeed each other without interval, as may be seen in the

Fig. 8.—Horse at Full Trot.—The dot placed in the notation corresponds with the attitude represented.

notation placed below the figure. The animal has been depicted from the notation. The instant which the artist has chosen is that marked in the notation by a white dot. At this moment, as the superposition indicates, the left fore-foot is at the end of its pressure; the right fore-foot is about to reach the ground; the right hind-foot is finishing its pressure, and the left hind-foot is about to fall.

The *elevated and lengthened trot* is represented in Fig. 8. The animal is depicted at the instant which in the notation is represented by a dot; that is to say, during the time of the suspension, at the moment when the left diagonal biped has just risen, and the right diagonal biped is about to descend.

Tracings afforded by the walking-pace are shown in Fig. 9. If we let fall a perpendicular from the points at which the curves commence, we shall have the positions of the successive impacts of the four legs. The order of succession of impacts is represented by the letters *A D*, *P G*, *A G*, *P D*, that is to say, *right fore-foot*, *left hind-foot*, *left fore-foot*, *right hind-foot*. The notation of the rhythm of the pressure of each foot, as derived from the registered curves, shows that the interval which separates the impacts is the same throughout, and consequently that the horse rests during the same time on the lateral as on the diagonal bipeds. This, however, is not always the case, some horses resting longer on the lateral biped than on the diagonal, and *vice versa*. The change of position of the centre of gravity may be seen by reference to Fig. 9. From 1 to 2 the horse will rest on the right lateral biped; from 2 to 3 on the right diagonal biped (that is to say, on that in which the *right* foot comes first); from 3 to 4 on the left lateral biped; from 4 to 5 on the left diagonal biped; again, from 5 to 6 the horse would find himself, as at the beginning, on the right lateral biped.

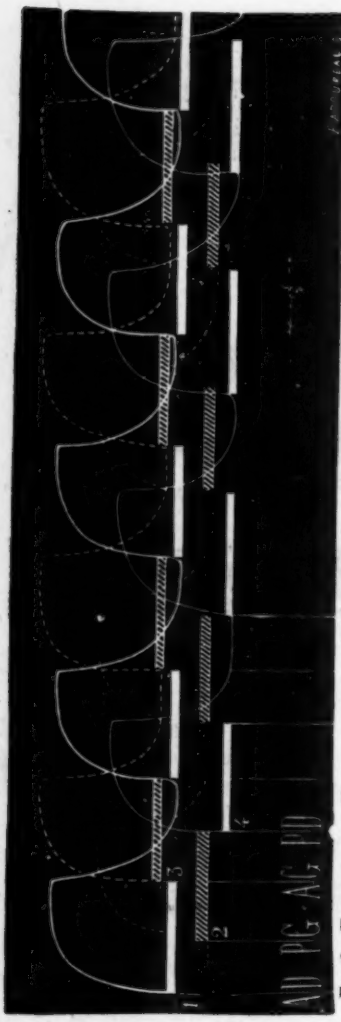

FIG. 9.—TRACINGS AND NOTATIONS OF THE WALKING-PACE, WITH EQUAL PRESSURES OF THE FEET, BOTH DIAGONALLY AND LATERALLY.

Observations on draught-horses have shown that, when the animal strives to react against a load, he may have three feet on the ground at once. This is held by some to be the rule in the normal walking-pace, but M. Marey has proved to the contrary. The vertical oscillations of the walk are chiefly at the withers, those of the croup being very slight. The actions of the hinder parts seem to consist chiefly

in a forward propulsion, with a scarcely perceptible impulsion of the body in an upward direction. This agrees with the theory quite generally admitted, that the fore-legs have little to do in the normal pace, except to support alternately the fore-part of the body, while to the hind-limbs belong the propulsive action and the tractive force exerted by the animal. Fig. 12 is a representation of the horse at a walking-pace. The instant is marked in the notation by a dot.

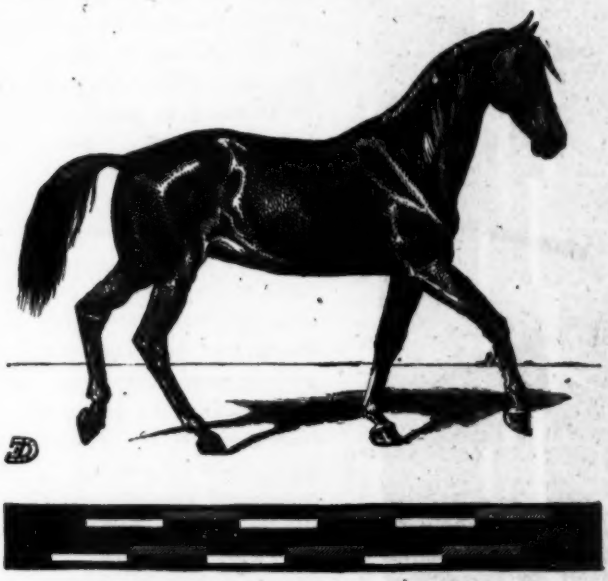

FIG. 10.—REPRESENTATION OF THE HORSE AT A WALKING-PACE.

The gallop comprises all those paces in which irregular impacts of the feet upon the ground recur at regular intervals. Most writers distinguish three kinds of gallop by the rhythm of the impacts, and name them, according to this rhythm, gallop in *two*, three, and four time. The most common kind is the gallop in three-time, from which the tracings in Fig. 11. have been obtained. At the commencement of the figure the animal is suspended above the ground; then comes the impact *P G*, which announces that the left hind-foot touches the ground. This is the foot diagonally opposed to that which the horse places forward in the gallop, and whose impact *A D* will be the last produced. Between these two impacts and in the middle of the interval which separates them, comes the simultaneous impact of the two feet forming the left diagonal biped. The superposition of the notations *A G*, *P D*, clearly shows this synchronism. In this series of movements the ear has therefore distinguished *three* sounds at nearly equal intervals. The first sound is produced by a hinder-foot, the second by a diagonal biped, the third by a fore-foot. Between the single impact

of a fore-foot, which constitutes the third sound, and the first beat of the pace which follows, there is a period of silence whose duration is exactly equal to that of the three impacts taken together; then the series of movements recommences.

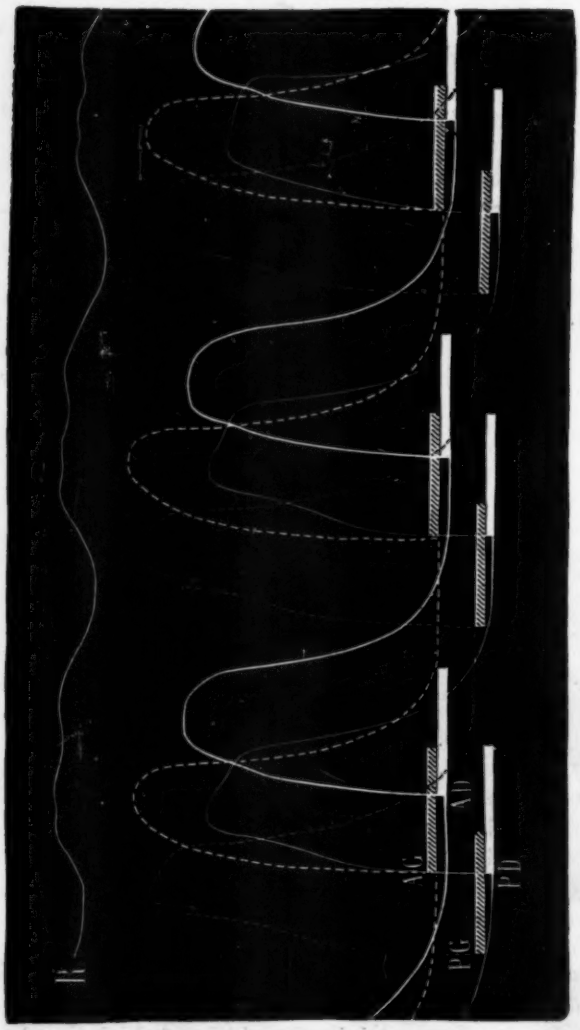

FIG. 11.—TRACINGS AND NOTATION OF THE GALLOP IN THREE-TIME.—*R*, curve of reactions taken at the withers. The curves of the reactions of the feet have a considerable extent, which shows the force of the pressures on the ground. The horse used for this experiment galloped with the right foot, as seen in the notation.

By an inspection of the curves, we see that the pressure of the feet on the ground must be more energetic in the gallop than in the paces already described, the height of the curves being greater than for either the trot or the walk. The greatest energy seems to belong to the first impact. At this moment, the body, raised for an instant from the ground, falls again, and one leg alone sustains the shock.

The notation, Fig. 12, enables us to follow (in *A*) the succession of impacts; and shows (in *B*) the succession of the limbs which cause these pressures on the ground. The reactions of this pace, produced at the withers, are seen in Fig. 11 (*R*). There is an undulatory elevation, which lasts all the time that the animal touches the ground; in

FIG. 12.—GALLOP IN THREE-TIME.—*A*, indication of three-time; *B*, indication of the number of feet which form the support of the body at each instant of the gallop in three-time.

this elevation are recognized the effects of the three impacts, which give it a triple undulation. The minimum elevation of the curve corresponds, as in the trot, with the moment when the feet do not touch the ground. Therefore, it is not a projection of the body into the air,

FIG. 13.—HORSE GALLOPING IN THE FIRST TIME (RIGHT FOOT ADVANCING), THE HIND LEFT FOOT ONLY ON THE GROUND.—The white dot, in the notation, corresponds with the instant at which the horse is represented.

which constitutes the time of suspension of the gallop. By comparing the reactions of this pace with those of the trot (Fig. 5), we see that in the gallop the rise and fall of the body are effected in a less sudden

manner. These reactions are, therefore, less jarring to the rider, though they may, in fact, present a greater amplitude.

The attitude of the horse at the moment of the first beat of the gallop in three-time is given in Fig. 13. The left hind-foot, on which the horse has just descended, alone rests on the ground.

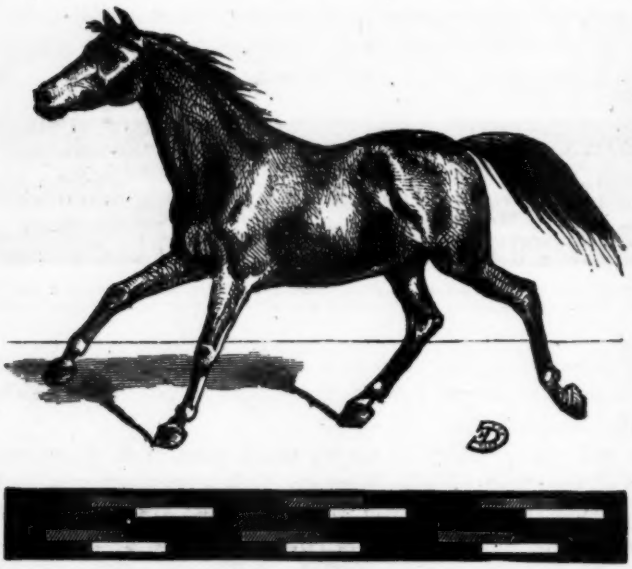

FIG. 14.—HORSE GALLOPING IN THE SECOND TIME (RIGHT FOOT FORWARD).

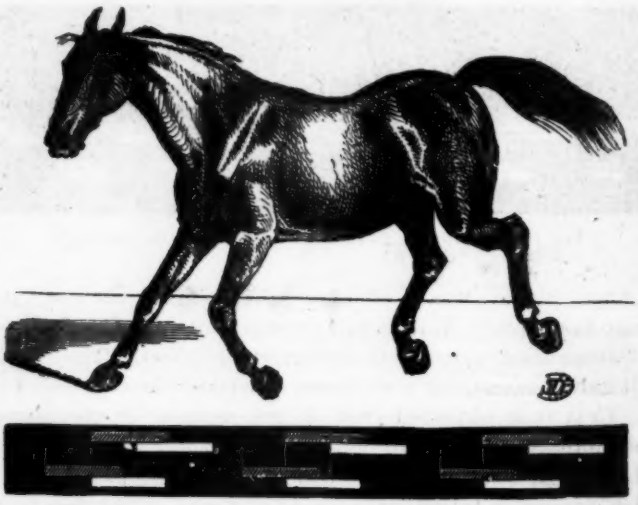

FIG. 15.—HORSE GALLOPING IN THE THIRD TIME (RIGHT FOOT FORWARD).

Fig. 14 is the position of the horse at the time of the second beat, or at the moment when the left diagonal biped has finished its impact;

the right fore-foot is about to reach the ground, the left hind-foot has just risen.

At the third or last beat of the pace, the position of the animal is that given in Fig. 15. The moment chosen is that in which the right foot alone rests on the ground, and is about to rise in its turn.

The gallop in four-time differs from that which has just been described only in this particular, that the impacts of the diagonal biped, which constitute the second beat of that gallop, are in this case disunited and give distinct sounds. This is shown in Fig. 16. Accord-

FIG. 16.—NOTATION OF THE GALLOP IN FOUR-TIME.—*A*, determination of each of the successive times; *B*, determination of the number of feet which support the body at each instant.

ing to this notation, the body, at first suspended, is borne successively on one foot, on three, on two, on three, and on one, after which a new suspension commences.

The full gallop, which is a very rapid pace, is in four-time. The impacts of the hinder-limbs, however, follow each other at such short intervals, that the ear can only distinguish one of them; but those of the fore-legs are notably more separated, and can be heard distinctly as two sounds. The notation of the full gallop (Fig. 17) confirms

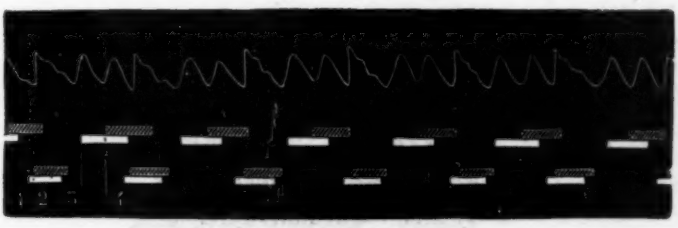

FIG. 17.—NOTATION OF FULL GALLOP; REACTIONS OF THIS PACE.

this. Another character of the full gallop is, that the longest period of silence takes place during the pressure of the hinder-limbs. The time of suspension appears to be extremely short. The reactions in the full gallop reproduce with great exactness the rhythm of the impacts. Thus it is observed that, at the moment of the almost synchronous impacts of the two hinder limbs, there is a sharp and prolonged reaction, after which two less sudden reactions take place, each of which corresponds with the impact of one of the fore-feet. The irregular line in Fig. 17 is the tracing of the reactions at the withers.

Many other points relating to the locomotion of the horse, such as

the characters of the footprints belonging to each pace; the transition from one pace to another; the modification of the movements incident to pulling a load, etc., we are unable to notice here, and would therefore refer the interested reader to M. Marey's work, where he will find the subject fully elucidated.

ODORS AND LIFE.

BY FERNAND PAPILLON.

TRANSLATED FROM THE MONITEUR SCIENTIFIQUE, BY A. R. MACDONOUGH.

DESCARTES, Leibnitz, and all the great minds of the seventeenth century, believed that phenomena are such interdependent parts of one whole, that they require to be explained by each other, and consequently, that a very close mutual connection should be maintained among the sciences. In their view, this was the condition of rapid advance and intelligent development. The experimental method, constant to systematic obstinacy in erecting so many barriers between the different sections of natural philosophy, has greatly hindered the completeness of whatever knowledge we possess as the result of mutual interaction among all truths. At this day, such barriers are tending to vanish of their own accord, and the science of man in his relations with external media begins to show the outlines of its plan and harmony. We have before this sketched several of its chapters, and we will endeavor now to write another, on the subject of odors.

I.

The seat of smell, or the olfactory sense, is the pituitary membrane lining the inner wall of the nostrils. It is a mucous surface, laid in irregular wrinkles, and receiving the spreading, slender, terminal filaments of a certain number of nerves. This membrane, like all other mucous ones, constantly secretes a fluid designed to lubricate it. By the aid of the muscles covering the lower part of the nostrils, the apparatus of smelling can be dilated or contracted, precisely like that of sight. This understood, the mechanism of olfaction is quite simple. It consists in the contact of odorous particles with the olfactory nerve. These particles are conveyed by the air to the inside of the nasal cavities, and there strike upon the sensitive fibres. If the access of air is prevented, or if the nerve is altered, no sensation is produced. Experiments in physiology, in fact, have settled that the olfactory nerves (or those of the first pair) are assigned exclusively to the perception of odors. Loss of the sense of smell occurs whenever the nerves are destroyed or injured by any process, or even whenever they are merely compressed. On the other hand, it is a matter of common observation

that impeding the passage of air into the nostrils is quite as effectual a way of making any sort of olfactory sensation impossible. Let us add, that the region most sensitive to odors is that of the upper part of the nasal cavities. There are, as we shall notice in proceeding, considerable differences as regards the degree of sensitiveness in this sense of smell, comparing one man with another. But it is a still more singular fact that sometimes, without apparent cause, the sense is utterly wanting. In other cases it is unaffected by the action of certain odors only, an analogous infirmity to that which students of the eye call *daltonism*, and which consists in the perception of certain colors only. We find in scientific annals the case of a priest who was insensible to all odors except that of a manure-heap, or that of decayed cabbage; and another, of a person to whom vanilla was entirely without scent. Blumenbach speaks too of an Englishman, with all his senses very acute, who perceived no perfume in mignonette.

Olfaction is sometimes voluntary, sometimes involuntary. In the former case, by an act which is called scenting something, and is resorted to for the sake of a keener sensation, we first close the mouth, and then sometimes draw in a full breath, sometimes a succession of short, quick inspirations. Then the muscular apparatus edging the opening of the nostrils comes into play, to contract that orifice, and point it downward, so as to increase the intensity of the current of inhaled air. When, on the contrary, we wish to smell as little as possible, the organ becomes passive. We effect strong expirations by the nose to drive out the air that produces scent, and inhalation, instead of being performed by the nostrils, instinctively takes place through the mouth.

Scents and the sense of smell have an important share in the phenomena of gustation, that is, there is a close connection between the perception of odors and that of tastes. Physiological analysis has clearly brought out the fact that most of the tastes we perceive proceed from the combination of olfactory sensations with a small number of gustatory sensations. In reality, there are but four primitive and radical tastes—sweet, sour, salt, and bitter. A very simple experiment will convince us of this fact. If we keep the nostrils closed when tasting a certain number of sapid substances, so as to neutralize the sense of smell, the taste perceived is invariably reduced to one of the four simple savors we have just named. Then, whenever the pituitary membrane is out of order, the taste of food is no longer the same; the tongue distinguishes nothing but sweet, sour, salt, or bitter.

It is time now to begin the study of the physiological and chemical conditions of smell, and for this we must first inquire how odorous substances behave with regard to the medium which separates them from our organs. Prévost, in an essay published in 1799 on the means of making emanations from odorous bodies perceptible to sight, was the first to bring to view the fact that certain odorous substances,

solid or fluid, placed on moistened glass, or in a saucerful of water, instantly act on those molecules of the liquid which they touch, and repel them more or less, producing a vacuum. He judged that this method might serve to make odors sensible to sight, and enable us to distinguish odorous from inodorous bodies. These movements of odorous bodies on the surfaces of liquids, of which camphor particularly gives so curious an instance, have lately been studied with the greatest care by a French physiologist, with a view to establishing a theory of odors. With this purpose Liégeois has examined most of the odoriferous substances, and has ascertained that almost all of them perform various motions of circulation and displacement on the surface of water, resembling those noted with camphor. Some act precisely as camphor does. Among these are benzoic acid, succinic acid, the rind of bitter oranges, etc. With others, motion soon stops, for they are quickly surrounded by an oily film which keeps them confined. Some must be reduced to powder before the phenomenon takes place. As regards odorous liquids, it occurred to Liégeois to saturate very light and spongy seeds, themselves odorless, with them, and he then found, on throwing the seeds on water, that circulatory and displacing movements took place, as with other substances. He concluded, from a series of experiments methodically tried, that the motions in question must be attributed, not to a release of gas, acting in the manner of a recoil, but simply to the separation and rapid diffusion, within the water, of the odorous particles. The volatility of substances cannot be admitted to have any part in explaining the phenomenon. It depends wholly on the affinity of fluids for the odorous particles, and also for those of fatty matter. Liégeois found, for instance, that a drop of oil put on the surface of water, without sensibly lessening in size, emits an enormous quantity of microscopic droplets, which are diffused through the mass of the water. Aromatic essences produce a like effect. Though insoluble in water, they have a powerful tendency to disperse themselves throughout it, and water that receives a very small quantity of the odoriferous principle, in the shape of extremely fine powder, has enough to gain their perfume completely. Liégeois's experiments give proof of the most diligent labors and of praiseworthy sagacity. Science has accepted them with satisfaction, and, after employing them usefully, will preserve the memory of their author, taken away in the flower of his age, at the outset of a noble career as a physiologist and surgeon.

It seemed, to quote his words, as though in these experiments we were assisting at the formation of the odorous molecules. Those delicate atoms emitted from odorous substances and diffused through the atmosphere are, in fact, the very same that impinge on our pituitary membrane, and give us the sensation of odors. Moreover, facts long ago observed display this revealing action, so to call it, of water upon odors. At morning, when the verdure is moist and the flowers

covered with sparkling pearls of dew, a fresher and balmier fragrance exhales from every plant. It is the same after a light shower. Vegetation gains heightened tints, at the same time that it diffuses more fragrant waves of perfume. We remark an effect of the same kind in the physiological phenomenon of taste. The saliva serves as an excellent vehicle for diffusing the odorous principles; then the movements of the tongue, spreading that fluid over the whole extent of the cavity of the mouth, and thus enlarging the evaporating surface, are clearly of a kind to aid the dispersion of the odorous principles, which, as we have seen, take a considerable part in the perception of tastes.

Now, in the phenomenon of smell, air acts in the place of water. It seizes the odorous particles and brings them into contact with the pituitary membrane. It is the vehicle, the solvent, of those extremely subtile atoms which, acting on the delicate fibres of the nerve, produce in it a special movement, which translates itself into the most varied sensations. Oxygen, and the existence in that gas of a certain proportion of odorous molecules, are the two essential conditions of this phenomenon.

Such is, at least, the result of earlier experiments, and of those performed of late years by Nicklès. A curious fact, well worthy of attention, is the remarkable diffusibility and degree of subdivision exhibited by some odorous substances. Ambergris just thrown up on the shore spreads a fragrance to a great distance, which guides the seekers after that precious substance. Springs of petroleum-oil are scented at a very considerable distance. Bartholin affirms that the odor of rosemary at sea renders the shores of Spain distinguishable long before they are in sight. So, too, every one knows that a single grain of musk perfumes a room for a whole year, without sensibly losing weight. Haller relates that he has kept papers for forty years perfumed by a grain of amber, and that they still retained the fragrance at the end of that time. He remarks that every inch of their surface had been impregnated by $\frac{1}{268106400}$ of one grain of amber, and that they had perfumed for 11,600 days a film of air at least a foot in thickness. Evidently the material quantity of the odorous principle contained in a given volume of such air is so minute as to elude imagination. We can readily conceive how philosophers cite such instances to give a notion of the divisibility of matter.

In fact, we are now considering matter emitted by odorous bodies. This shows that they do not act as centres of agitation, occasioning vibrations which pass in waves to our organs, to exert on them a purely dynamic influence. This giving off of odorous matter, with the necessary aid of oxygen in the atmosphere, proves, too, that odors are in no respect comparable to light or heat, which one may regard in an abstract way, in the immaterial and ethereal space which is the region of their motion, as proper forces, and acting from a distance. Odors, to be perceived, must be taken up by oxygen, and borne by it

to the organ of smell. In a word, odor is the odoriferous particle itself, while light is not the light-giving body.

Does oxygen exert a chemical influence on those atoms of which it robs odorous substances? We do not know, neither do we know of what kind is the action which occurs on the contact of odor with the olfactory nerve, whether the phenomenon is a mere mechanical agitation, or whether some chemical decomposition takes place in the case. At any rate, it is allowable to reason from the observed facts that smell and taste are two senses peculiarly distinct from the others, as well with respect to the object of sensation as to the ideas which the mind derives from the sensation itself. Sight, touch, and hearing, in a manner physical senses, furnish us the ideas of external forms, harmonies, and motions. They introduce us to the conception of the beautiful, and are true fellow-laborers with the intellect. Taste and smell are rather chemic senses, as Nicklès calls them. They come into action only upon contact, and awake in us only such sensations as life and mind gain no profit from. While the former are the spring of the highest functions, the latter are of use only for the performance of acts of nutrition.

The learned and capable author[1] of a book on odors, published within a few years, fancies, however, that he can establish a kind of æsthetics of odors, more or less resembling that of tones. He has investigated olfactory harmonies, hoping to find in them the elements of a sort of music. "Odors," he says, "seem to affect the olfactory nerves in certain definite degrees, as sounds act on the auditory nerves. There is, so to speak, an octave of smells, as there is an octave of tones; some perfumes accord, like the notes of an instrument. Thus almond, vanilla, heliotrope, and clematis, harmonize perfectly, each of them producing almost the same impression in a different degree. On the other hand, we have citron, lemon, orange peel, and verbena, forming a similarly associated octave of odors, in a higher key. The analogy is completed by those odors which we call half-scents, such as the rose, with rose-geranium for its semitone; 'petit-grain' and neroli, followed by orange-flower. With the aid of flowers already known, by mixing them in fixed proportions, we can obtain the perfume of almost all flowers." In accordance with these fancies, Piesse has formed gamuts of odors, parallel with musical gamuts, and exhibiting concords of scents at the same time with those that produce discords. As a painter blends his tints, the perfumer should blend his fragrances; and Piesse maintains he can only gain that object by following the laws of harmony and contrast in odors. This theory is certainly quite ingenious, and deserves attention, but it is open to serious objections. If the harmony of colors and of sounds exists, it is because optics and acoustics are exact sciences, and harmony in this case is reduced to numerical relations,

[1] Piesse, on "Odors, Perfumes, and Cosmetics."

determined in a positive way. These relations, as concerns odors, can have no other basis than a capricious and relative sensibility. They are thus incapable of being reduced to form, *a fortiori* of being translated into fixed precepts.

To complete these details, it remains to say something of the delusions of the sense of smell; for this sense, like the others, has its aberrations and hallucinations. The delusions of smell are hardly ever isolated; they accompany those of hearing, sight, taste, and touch, and are also less frequent than the latter. Insane people, who are affected by them, complain of being haunted by fetid emanations, or congratulate themselves on inhaling the most delicious perfumes. Lelut mentions the case of a woman, an inmate of la Salpêtrière, who fancied that she constantly perceived a frightful stench proceeding from the decay of bodies she imagined buried in the courts of that institution. Impressions of the kind are usually very annoying. Brierre de Boismont relates the account of a woman affected by disorder of all her senses. Whenever she saw a well-dressed lady passing, she smelt the odor of musk, which was intolerable to her. If it were a man, she was distressingly affected by the smell of tobacco, though she was quite aware that those scents existed only in her imagination. Capellini mentions that a woman, who declared that she could not bear the smell of a rose, was quite ill when one of her friends came in wearing one, though the unlucky flower was only artificial.

Such facts might be multiplied; but, as they are all alike, it is not worth while to mention more of them. The latest observations made in insane asylums, among others, those of M. Prévost, at la Salpêtrière, have shown also that these delusions and perversions of the sense of smell are more common than had hitherto been supposed among such invalids, and that if they usually pass unnoticed, it arises from the fact that nothing spontaneously denotes their existence.

The intensity and delicacy of the sense of smell vary in mankind among different individuals, and particularly among different races of men. While some persons are almost devoid of the sense of smell, others, whose history is related in the annals of science, have displayed a refinement and range in the distinction of odors truly wonderful. Woodward, for instance, mentions a woman who foretold storms several hours before their coming, by the help of the sulphurous odor, due probably to ozone, which she perceived in the atmosphere. The scientific journals of the day relate the account of a young American girl, a deaf-mute, who, by their odor alone, recognized the plants of the fields which she collected. Numerous instances, moreover, prove that in savage races this sense is very greatly more developed than among civilized men. It is a traveler's story, that some tribes of Indians can pursue their enemies and animals of the chase by mere scent.

But it is among the other mammals that we find the sense of

smell displayed in its highest degree of power and perfection. Among ruminants, some pachyderms, and particularly among carnivorous mammals, the olfactory membrane attains the keenest sensitiveness. Buffon has described these animals with extreme exactness, in saying that they smell farther than they see, and that they possess in their scent an eye which sees objects not only where they are, but even wherever they have been. The peculiarity of scent in the dog is too well known to need more than an allusion.

If we can hardly give faith to those ancient historians who relate that vultures were attracted from Asia to the fields of Pharsalia by the smell of the corpses heaped together there after a famous battle, yet we must accept the assertions of naturalists so well qualified to observe as, for instance, Alexander von Humboldt. The latter relates that in Peru, and other countries of South America, when it is intended to take condors, a horse or cow is killed, and that in a short time the smell of the dead animal attracts a great number of these birds, though none had before that been seen in the country. Other more extraordinary facts are told by travelers. These must usually be received only with the greatest caution, because in most cases the sense of smell gains credit for what is due to the sense of sight, which, with these birds, is very keen and far-reaching. Yet, making allowance for exaggeration, it must be admitted that these animals have a very highly-developed sense of smell. Scarpa, who has made admirable researches on this subject, found that they refuse food which is saturated with odorous substances, and, as an odd instance, that a duck would not swallow perfumed bread till after it had washed it in a pond. The waders, which have the largest olfactory nerves, are also those birds that display the greatest keenness of scent. Reptiles have very large olfactory lobes, leading us to believe that they discern odors readily, but at present we know little of the impressions they are sensitive to in this respect. Fish also have an olfactory membrane. Fishermen have always remarked that they may be attracted or driven off by throwing certain odorous substances into the water. Sharks, and other voracious fish, collect in crowds and follow from very far about a body thrown into the sea. It is even said that, when blacks and whites are bathing together in latitudes where these fish abound, they particularly single out and pursue the more strongly odorous blacks. Nor are the crustacea indifferent to emanations which act on the olfactory nerve. The method used for attracting and taking crabs is familiar.

Regarding the lower animals we have only still more uncertain information, except as to insects. Entomologists maintain that scent is very delicate in most insects, and rely on plausible conjectures on this subject, but they do not as yet know what the seat of the sense of smell in insects is. When meat is exposed to the air, in a few moments flies make their appearance in a place where none had before

been seen. If refuse matter or bodies of animals are left on the ground, insects flock to them at once, feeding on such substances, and depositing their eggs in them. Scent alone seems to guide them, exclusively of sight even, for, if the object of their desire is hidden, they easily manage to find it. A curious fact as to the scent of insects is furnished by those kinds that prefer decaying substances. A beautiful arum is found in our woods, the cuckoo-pintle, whose white flower diffuses a disgusting odor. Now, the inside of this flower is often filled with flies, snails, and plant-lice, seeking the putrid source of this fetid smell. We may see the little creatures, in quest of their food or of a fit place to lay their eggs, move about in all directions, and quit most unwillingly the flower whose scent has misled them.

II.

Having thus learned what physiologists think of the sense of smell and the conditions of the perception of odors, let us see what naturalists and chemists have ascertained respecting the latter as viewed in themselves, what place they give to odorous bodies, and what character they attribute to them all. The three kingdoms possess odors. Among mineral substances, few solids, but quite a number of liquids and gases, are endowed with more or less powerful scents, in most cases not very pleasant ones, and usually characteristic. Those odors belong to simple substances, such as chlorine, bromine, and iodine; to acids, as hydrochloric and hydrocyanic acid; to carburets of hydrogen, as those of petroleum; to alkaline substances, ammonia, for instance, etc. The odors observable among minerals may almost all be referred either to hydrocarbonic or hydrosulphuric gases, or to various solid and liquid acids produced by the decomposition of fats, or to peculiar principles secreted by glands, such as musk, ambergris, civet, and the like. Vegetables present quite another variety of odors, from the faintest to the rankest, from the most delicious to the most disgusting. Absolutely scentless plants are very rare, and many, that seem to be so while they are fresh, gain, on drying, a very decided perfume.

The odor of plants is due to principles very unequally distributed throughout their different organs; some solid, as resins and balsams, others which are liquid, and known by the name of essences or essential oils. In most cases the essence is concentrated in the flower, as occurs with the rose and the violet. In other plants, as in bent-grass and Florence iris, only the root is fragrant. In cedar and sandal wood, it is the wood that is so; in mint and patchouli, the leaves; in the Tonquin bean, the seed; in cinnamon, the bark, which is the seat of the odorous principle. Some plants have several quite distinct fragrances. Thus the orange has three: that of the leaves and fruit, which gives the essence known by the name of "petit-grain;" that of the flowers, which furnishes neroli; and again the rind of the fruit,

from which essence of Portugal is extracted. A great number of vegetable odors belong exclusively to tropical plants, but the flora of Europe furnishes a large proportion of them, and almost all the essences used in perfumery are of European origin. England cultivates lavender and peppermint largely. At Nîmes, gardeners are particularly attentive to rosemary, thyme, petit-grain, and lavender. Nice has the violet for its speciality. Cannes extracts all the essences of the rose, the tuberose, cassia (the yellow acacia), jasmine, and neroli. Sicily produces lemon and orange; Italy, bergamot and the iris.

What, now, is the chemical nature of the odorous principles in plants? The chemistry of to-day reduces almost all of them to three categories of well-ascertained substances: hydrocarburets, aldehydes, and ethers. We will endeavor to give a clear account of the constitution of these three kinds of substances, and to mark their place in the register of science. The hydrocarburets are simple combinations of carbon and hydrogen, as, for instance, the petroleum-oils. They represent the simple compounds of organic chemistry. As to aldehydes and ethers, their composition is rather more complex; besides carbon and hydrogen, they contain oxygen. Every one knows what chemists mean by an alcohol; it is a definite combination of hydrogen, carbon, and oxygen, neither acid nor alkaline, which may be regarded as the result of the union of a hydrocarburet with the elements of water. Common alcohol, or spirits of wine, is the type of the most important series of alcohols, that of the mono-atomic alcohols. Chemists represent it by the formula C^2H^6O, to indicate that a molecule of it arises from the union of two atoms of carbon with six atoms of hydrogen and one of oxygen. Independently of the alcohols, which are of great number and varying complexity, organic chemistry recognizes another class of bodies, of which vinegar is the type, and which receive the name of organic acids, to mark their resemblance to mineral acids, such as oil of vitriol or aqua-fortis. Now, every alcohol, on losing a certain amount of hydrogen, gives rise to a new body, which is called an aldehyde; and every alcohol, on combining with an acid, produces what is called an ether. These rapid details allow us to understand precisely the chemical character of the essences or essential oils which plants elaborate within their delicate tissue. Except a small number among them which contain sulphur, as the essences of the family of crucifers, they all present the same qualitative composition—carbon and hydrogen, with or without oxygen. Between one and another of them merely the proportion of these three composing elements varies, by regular gradations, but so as always to correspond either to a hydrocarburet, or to an aldehyde, or to an ether. In this case, as in almost the whole of organic chemistry, every thing is in the quantity of the composing elements. The quality is of so little importance to Nature, that, while following always the same laws, and constantly using the same materials, she can, by merely changing the

ponderable relations of the latter, produce, by myriads of various combinations, myriads of substances which have no resemblance to each other. The strange powers of the elements and the mysterious forces concealed in matter make themselves known to us in a still more remarkable phenomenon, to which the name of *isomery* is given. Two bodies, thoroughly unlike as regards their properties, may present absolutely the same chemical composition with respect to quality and quantity of elements. "But in what do they differ?" it may be asked. They differ in the arrangement of their molecules. Coal and the diamond are identical in substance. Common phosphorus and amorphous phosphorus are one and the same in substance. Now, the odorous principles of plants offer some exceedingly curious cases of isomery. Thus the essence of turpentine, the essence of lemon, that of bergamot, of neroli, of juniper, of savin, of lavender, of cubebs, of pepper, and of gillyflower, are isomeric bodies, that is, they all have the same chemical composition. Subjected to analysis, all these products yield identical substances in identical proportions, that is, for each molecule of essence, ten atoms of carbon, and sixteen atoms of oxygen, as denoted by their common formula, $C^{10}O^{16}$. We see how these facts as to isomery prove that the qualities of bodies depend far more on the arrangement and the inner movements of their minute particles, never to be reached by our search, than on the nature of their matter itself; and they show, too, how far we still are from having penetrated to the first conditions of the action and forces of substances. Among odoriferous essences placed by chemists in the class of aldehydes may be named those of mint, rue, bitter almonds, anise, cummin, fennel, cinnamon, etc. The rest are ranged in the great series of ethers, which vary greatly in complexity, notwithstanding the simple uniformity of their primary elements.

Such is the chemical nature of most of the odorous principles of vegetable origin. But chemistry has not stopped short with ascertaining the inmost composition of these substances; it has succeeded in reproducing quite a number of them artificially, and the compounds thus manufactured, wholly from elements, in laboratories, are absolutely identical with the products extracted from plants. The speculations of theory on the arrangements of atoms, sometimes condemned as useless, do not merely aid in giving us a clearer comprehension of natural laws, which is something of itself, but they do more, as real instances prove; they often give us the key to brilliant and valuable inventions. An Italian chemist, who was then employed in Paris, Piria, in 1838, was the first who imitated by art a natural aromatic principle. By means of reactions suggested by theory, he prepared a salicilic aldehyde, which turned out to be the essence of meadow-sweet, so delicate and subtile in its odor. A few years later, in 1843, Cahours discovered methylsalicilic ether, and showed that it is identical with the essence of wintergreen. A year after, Wertheim com-

posed essence of mustard, while believing himself to be making only allylsulphocyanic ether. These discoveries produced a sensation. Nowadays the chemist possesses the means of creating many other natural essences. Common camphor, essence of bitter-almonds, that of cummin and of cinnamon, which are aldehydes, as we have seen, may be prepared without camphor-leaves or almonds, without cummin or cinnamon. Besides these ethers and aldehydes whose identity with essences of vegetable origin has been proved, there exist, among the new bodies known to organic chemistry, a certain number of products formed by the union of common alcohol or amylic alcohol with different acids, that is to say, of ethers, which have aromatic odors more or less resembling those of some fruits, but as to which it cannot yet be affirmed that the odors are due to the same principles in both cases. However this may be, perfumers and confectioners, more industrious and wide-awake than chemists, have immediately made good use of these properties. Artificial aromatic oils made their first appearance at the World's Fair of London in 1851. There was there exhibited a pear-oil, diffusing a pleasant smell like that of a jargonel, and employed to give an aroma to bonbons. This product is nothing else than a solution of amylacetic ether in alcohol. Apple-oil was exhibited beside the pear-oil, having the fragrance of the best rennets, and produced by dissolving amylvaleric ether in alcohol. The commonest essence was that of pineapple, which is nothing else than ordinary butyric ether. There was observed, too, an essence of cognac, or grape-oil, used to impart to poor brandies the highly-prized aroma of cognac. The product which was then, and still is, the most important article of manufacture, is the essence of "mirbane," which very closely resembles in its odor that of bitter almonds, and which commerce very often substitutes for the latter. Essence of mirbane is nothing else than nitrobenzine, which results from the action of nitric acid on benzine. Benzine, in turn, is met with among the products of distillation of tar, which also yield the substances used in preparing those beautiful colors called aniline. Besides the essences we have just mentioned, which are gaining an increasing importance in the manufacturing arts, artificial essences of quinces are also prepared, and essences of strawberries, of rum, etc. All these preparations serve, it must be admitted, to give an aroma to the cordials, confectioneries, and sweetmeats, which are so largely sold nowadays. In other words, the products of industry are constantly taking the place of those of Nature more and more. In all these cases, these instances of composition of odorous principles are among the finest triumphs of organic chemistry. The creative power of the chemist is ever widening its range. After the labors of Piria, Wertheim, and Cahours, came those of Berthelot, who has imitated the fatty matters of the animal economy. We are at this moment in progress toward the artificial manufacture of sugar. If we succeed in that, nothing more

will remain but to effect the composition of albuminous substances, in order to give us the complete mastery of the processes which Nature follows in her elaboration of immediate principles. That gift of making its object a reality, which is the peculiar privilege of chemistry, is also one of the strongest arguments to bring in proof of the absoluteness of those laws which we ascertain respecting the system of forces external to us.

Linnæus, whose mind was remarkably analytical and classifying, has not only arranged vegetables and animals in order, but has also classified diseases, and even odors. He refers the latter to seven classes: aromatic odors, such as that of laurel-leaves; fragrant, like those of lilies and jasmine; ambrosial, such as amber, musk, etc.; garlicky, like that of garlic; fetid odors, like those of the goat, the orrage, and others; disgusting odors, as those of many plants of the solaneæ order; and, last of all, nauseous odors. The terms of Linnæus have generally become current in language, but we understand, of course, that their value is merely conventional. As we have said before, there is no standard for the comparison of odors. We can only describe them by making comparisons between them, according to the degrees of resemblance existing between the impressions with which they affect our olfactory membrane. They have no qualities capable of being rigorously defined. This is the reason why it is impossible to give them any natural classification.

III.

The sensations produced by smells are perceived and judged of in a great variety of ways, though with less of difference than prevails as to tastes. "I have seen a man," says Montaigne, "fly from the smell of apples quicker than from a cannonade." The instance he alludes to in this passage is that of Quercet, Francis I.'s secretary, who rose from table and took flight whenever he saw apples upon it. History tells us that Louis XIV. could not bear perfumes. Grétry was greatly annoyed by the odor of roses; that of a hare caused Mdlle. Contat to faint. Odors which disgust us, like that of asafœtida and of the valerian-root, are on the contrary highly enjoyed by the Orientals, who use these substances for condiments. Among other singular instances related by Cloquet on this subject, we will mention that of a young girl who took the greatest delight in inhaling the scent of old books, and that of a lawyer to whom the exhalations of a dunghill yielded the most agreeable sensations. So that it is out of our power to fix general rules with respect to the influence of odors on our organs, and the character of the sensations which they effect in us; still, from a purely physiological point of view, it is certain that some of them exercise a uniform influence. Chardin and other travelers mention that, when musk-hunters take from the animal the pouch containing musk, they must have the nose and mouth covered by a

cloth doubled in several folds, if they would escape violent hæmorrhage.

The smell of the lily, the narcissus, the tuberose, the violet, the rose, the elder, etc., when it reaches a certain point of concentration, usually exerts an injurious influence on the system. It occasions more or less severe headaches, fainting-fits, and sometimes even more serious disorders. Some odors, which have an agreeable perfume in a state of considerable diffusion, gain when concentrated a noxious and sometimes dangerous smell. This is particularly true of civet, patchouli, and the essences of neroli and thyme. Scientific records mention several cases of death occasioned by the poisonous action of some odorous emanations. It has been remarked that plants of the family of labiates, such as sage, rosemary, etc., offer in this respect no sort of risk, and seem rather to enjoy wholesome properties. Yet it is of consequence at this point to distinguish between the action of the odor which is in a manner purely dynamic, the intoxication from the essence, and the effect of carbonic acid thrown off by plants. These three influences have often been confounded by authors who have recorded accidents occurring after the inhalation, more or less prolonged, of odoriferous air.

This variable action of odors on the nervous system, sometimes wholesome, sometimes noxious, explains the part they have always played in the various circumstances of life among mankind. It would need a volume to relate the religious, political, economic, and gallant history of odors and perfumes. We must be content here with noticing its chief lessons, as far as they are connected with the physiological theory which is the basis of this study. For there is unquestionably something instinctive at the bottom of these general and uniform customs which exhibit the affinity of man for odors. Doubtless we must recognize in this rather a refinement of sensuality than a natural craving; but the same result has occurred in this case as in the instance of beverages, of music, etc. Habit has become in some sort a second nature; the senses have acquired a taste for that especial intoxication which beguiles them and disguises painful realities for them.

It is in religion, in the first place, that we observe the use of perfumes. Nothing holy or lofty was conceived of in which their influence was not present. Perfumes won the gods to give ear to the vows addressed to them in temples where burning incense diffused its fragrant clouds. From the highest antiquity we find that the priests of different religions avail themselves of the use of odoriferous substances. Five times a day the disciples of Zoroaster laid perfumes upon the altar where the sacred flame glowed. Moses, in Exodus, recorded the composition of two perfumes used in the sacred rites. The Greeks assigned a leading place to odors in their ingenious fictions of theology. They believed that the gods always declare their presence by an

ambrosial fragrance, as Virgil tells us, in speaking of Venus;[1] and Moschus, describing Jupiter transformed to a bull. The use of perfumes in religious ceremonies had for its purpose the excitement of a sort of intoxication in the priests and priestesses, and also to disguise the smell of blood and of decaying matters, the offal of the sacrifices. The Christian religion borrowed from paganism the use of perfumes in the rites of worship. There was even a period at which the Church of Rome owned estates in the East devoted exclusively to plantations of trees yielding balsamic resins.

Besides these uses, odors were, in old times, still oftener employed in private life. Nothing surprises us more, in reading the ancient authors, than their relations on this subject. Among the Jews, the use of perfumes was restrained within proper limits, by the regulations of the Mosaic law, which consecrated them to worship. But, with the Greeks, it reached an extraordinary height and refinement. They kept their robes in perfumed chests. They burned aromatic substances during their banquets; they scented their wines; they covered their heads with fragrant essences at their festivals. At Athens, the perfumers had shops which were places for public resort. Apollonius, a scholar of Theophilus, left a treatise on perfumes which proves that, even as regards the extraction of essences, the Greeks had attained astonishing perfection. Neither Solon's laws nor Socrates's rebukes could check the progress of that passion. The Romans inherited it from Greece, and enlarged the stock of Eastern perfumes by those of Italy and Gaul. They used them profusely to give fragrance to their baths, their rooms, their beds, and their drinks. They poured them on the heads of guests. The awning shielding the amphitheatre was saturated with scented water, which dripped, like a fragrant rain, on the spectators' heads. The very Roman eagles were anointed with the richest perfumes before battle. At the funeral of his wife Poppæa, Nero burned on the pyre more incense than Arabia yielded in a whole year. It is related, too, that Plancius Plancus, proscribed by the triumvirs, was betrayed by the perfumes he had used, and thus discovered to the soldiers sent to pursue him. Besides the odors extracted from mint, marjoram, and the violet, which were the most common, the ancients made much use of the roses of Paestum, and various aromatic substances, such as spikenard, megalium, cinnamon, opobalsamum, etc.

It is singular to notice that the use of perfumes, brought to Rome with Grecian manners, was in its turn conveyed to France and Northern Europe with Latin manners, and chiefly by the Romish religion. It is from religious rites, indeed, that it passed into ceremonies of state, and thence into private life. Among the presents sent by

[1] "Then, as the goddess turned, a rosy glow
Flushed all her neck, and from her head the locks
Ambrosial breathed celestial fragrance round."

Haroun-el-Raschid to Charlemagne were many perfumes. In the middle ages, among princes and men of highest rank, they washed their hands with rose-water, before and after eating; some even had fountains from which aromatic waters flowed. At this period, too, it was the custom to carry the dead to their burial-place with uncovered face, and to place little pots full of perfumes in the coffins. The French monarchy always showed an unrestrained passion for enjoyments of this nature, which seemed created as a necessary attendant upon all others. Marshal Richelieu had so extravagantly indulged his passion for perfumes under every form, that he had lost the perception of them, and lived habitually in an atmosphere so loaded with scents that it made his visitors ill. Madame Tallien, coming from a bath of juice of strawberries and raspberries, used to be gently rubbed with sponges saturated with perfumed milk. Napoleon I. every morning poured eau-de-Cologne, with his own hands, over his head and shoulders.

IV.

Above all these questions which we have just skimmed, there rises another, of a graver and more mysterious kind, one which occurs at the end of all studies that treat of sensation, and with regard to which some reflections will not be out of place here. To what, outside of us, do those sensations which we experience within us correspond? What relation is there between the real world and that image of the world shadowed in our soul? In the special case we are concerned with, what is it in these substances which is the cause why they affect our sense of smell? It seems certain, in the first place, that odor in itself, so far as it is odor, is a mere figment of our mind. Contemporaneous physiology proves that excitement of the nerves of sensation is followed, in each one, by the sensation that corresponds with each. When we electrify the eye, we call up in it an appearance of light; when we electrify the tongue, we produce in it a sensation of taste; when we electrify the inside of the ear, we provoke in it the effect of a sound. So, too, a similar excitement, electric or otherwise, of the olfactory nerves, creates in our mind the sensation of smell, even though no odorous molecule takes part in the phenomenon. Sensation, therefore, seems to depend chiefly on the nature of the sensitive nerve. The external world seems to contribute to it only by setting in motion the nerve-fibres. Even this condition of an impulse impinging from without is not indispensable, since, in sleep and in madness, we experience sensations of smell which, by the testimony of our other senses, answer to no external agent. Still, we believe that we can distinguish cases of hallucination from cases of true perception; still, we maintain that there are, outside of ourselves, distinct causes of our distinct sensations. No skepticism has prevailed, nor will prevail, against this testimony of the most powerful evidence which exists in

our inmost being. How can we account for this apparent contradiction? In reality, there is no contradiction. Observe, indeed, that, even if the most indifferent causes can effect in us one and the same sensation, and thus delude us as to the outer world, our soul is never cheated. It knows perfectly well how to refer this one sensation to the dissimilar objective causes which have affected it; in other words, the causes which are alike, and are confused in one in the purely physiological act of sensation, divide and grow distinct in the psychological act by which the soul recognizes them, and conceives them as different. If we had, to give us knowledge, only the dull and ignorant passivity of our senses, there would be no reality for us; but the wise activity of the soul can not merely assert the reality of outward objects, for a reason similar to that which makes it assert its own existence—it can still further argue, from its various modes of affection, to a corresponding variety of external forces. It moves in harmony with the world, rather than in harmony with the senses. In presence of the latter, it is like a good prince, who would be nothing without his subjects, but who regulates and civilizes them, by giving them laws, and ruling their morals. Thus, and this is the conclusion at which we aim, it is in the soul, regarded as the focus of all those rays refracted through the senses, as the central light outshining all others, that we must set the power and the right to discern what the senses do not discern, and to pierce to a depth forever beyond their reach. We shall never know what relation there is between the outward world and those images of it which we perceive, but the soul can hold the unshaken belief that the various points of those images correspond to points in the outer world situated in a like order, and that the forces which affect it are, in their essence, of the same nature as those forces of which, in its inmost depths, it feels itself the lord.

THE NATURAL HISTORY OF THE OYSTER.

By Rev. SAMUEL LOCKWOOD, Ph. D.

II.

IN the former article, attention was given chiefly to what might be called structural and industrial considerations of our bivalve. We are now to note some matters in the life of the oyster of a natal character. Its friends and enemies must be looked after. Its dietetics and geographical range must be dealt with. It must also be viewed in certain geological and ethnological aspects; for we may find even the oyster holding a singular relation to the American autocthonic man.

The Oyster's Birth and Growth.—According to the popular

notion, which, in the main, is correct, the spawning-season of the oyster embraces those months which have no *r* in their spelling, namely, May, June, July, and August, the four warm months of the year. The fact is, that oysters generally do their spawning during these four months; but a few are liable to spawn whenever the water is warm enough, and large numbers pass through the year without spawning; and these, were it not for the difficulty of assorting them, would be available for food at any time. But the prejudice is universal against

FIG. 1.—GROUPS OF EUROPEAN OYSTERS, OF DIFFERENT AGES, ON A STICK OF WOOD.

their use during the *r*-less months. That they are not in as good condition then as during the cooler months, is reasonable to suppose; but that they are all necessarily unwholesome in the warm months, is far from being proved. In business phrase, oysters in spawning-time are said to be "milky." This means the presence of an opaline fluid in considerable abundance, and which has to do with the wants of its

young—perhaps, remotely, a sort of fluid amnion. Our bivalve, however, does not spawn after the manner of mollusks generally. It is in its own way viviparous. It does not emit eggs; but, at the proper time, sends forth its young alive. The eggs are dislodged from the ovaries, and committed to the nursing care of the gill and mantel. At first, each egg seems to be inclosed in a capsule. It is of a yellowish color; but, as incubation or development progresses, the color changes, first to a gray, then to a brown, afterward to a violet. This is a sign that the time of eviction is at hand; for Nature now issues her writ to that effect. And wonderful little beings they are when the writ arrives to vacate the homestead; for whole troops of them can go gracefully, and without jostling, through the maziest evolutions in that tiniest sphere—a drop of water. As cited by F. W. Fellowes, in the *American Naturalist*, says M. Davaine: "Nothing is more curious than to see, under the microscope, these little mollusks travel in a drop of water, in vast numbers, mutually avoiding one another, crossing each other's track in every direction, with a wonderful rapidity, never touching, and never meeting." The parent-oyster has, indeed, a prodigious family to turn out upon the world. But when this time does come, though winter be near, her actions are summary, and the wee bairns are every one ordered from home. They are spit forth, or ejected from the shell. Filled with water, the valves are suddenly snapped together. Every snap emits a small, whitish cloud. Though a little of the milky fluid be in it, this whitish cloud is composed chiefly of the tiny fry; for, individually, they are almost invisible. Indeed, who shall count the oyster's offspring? Science, by her own methods,

FIG. 2.—THE SPAT.—OYSTERS JUST BORN, HIGHLY MAGNIFIED.

has made the computation; and so she gives us the astounding assurance that a single oyster, during one spawning-season, emits two million embryos! Each one, though scarcely larger than a pin-point, is a lively little affair; and such an odd little fellow, too! In fact, it has scarcely any resemblance to its parent, either in external form or internal anatomy; while, in habit, it differs as widely as does the flying bird from the burrowing mole. Let us look a moment at Fig. 2. These are young oysters just sent into the world. They are not so large, by a good deal, as an ordinary pin's-head. How angular the shell is! And the internal organization is, as yet, very simple. And

what a strange, brush-like appendage! That fleshy pad is its locomotive organ; and a very funny, but quite pretty contrivance it is. The projected pad is encircled by a frill of cilia, or fleshy hairs, arranged much as the frill is around the large pin-cushion which occupies a place before the mirror of a lady's boudoir. As these cilia play together, the illusion is produced of a revolving wheel; and, in fact, it is the uni-cycle velocipede of this baby-voyager, with which it must do some traveling in quest of a home, or permanent settlement for life. This frilled organ can be projected and withdrawn in rapid alternations. While being projected, the circular frill expands, thus achieving a very efficient propulsion. And, while being withdrawn, it contracts, or is involved within itself, in this way presenting the least possible resistance to the water. This mechanism, as I understand it, is as remarkable as it is beautiful. It fulfills perfectly, or certainly to a remarkable degree, the conditions of perhaps the most perplexing of the unsolved practical problems in naval science—the attainment in union of the maximum power of propulsion and the minimum resistance from back-water.

If we examine a snail, or conch, as typical of the univalve mollusks, or shell-fish, we shall find the organs of sense, mouth, tentacles, and eyes, so arranged together as to entitle the object to be known as a cephalate mollusk, that is, one which has a head. The bivalves are not so highly organized, and are acephalate, or headless. It is a curious fact, however, that in the larval state many of these bivalves have eyes, though they lose them as growth proceeds. Although we think it probable, it has not yet been proved, that the larval oyster has eyes. To witness the merry high time of these juveniles, it would seem that they both have eyes and are bound to use them, too, in seeing something of the world; for, as if eviction entailed neither disgrace nor inconvenience—as with certain bipedal juveniles under pupilage—off they go in the wildest glee imaginable. But the gay frolic is soon over. A few settle down, like the old folks, to a sober life. Alas! it is with the rollicking young oysters as with many other young people—this wild-oat sowing yields a fruitful but perilous harvest. Of each million that enter upon this dissipation, but a few hundreds, at the most, survive. Many have been devoured by hungry enemies lying in wait, and many went to sea, and, unable to return, perished miserably. The survivors attach themselves to any thing that offers an anchorage; and these are called "spat." Fig. 1 contains five groups of oysters of as many different ages, all of which, by a professional oysterman, would be called "spat," excepting the three largest at the top. The attachment is made at the lower valve. And, now having wound up its giddy career, what was done with the velocipede? In plainer words, what is to become of the locomotive pad, for which it has no further use? It begins to disappear—not by atrophy, however, nor is it sloughed off in any way. Herein appears

one of Nature's economic processes; for the pad is *absorbed*, literally consumed, and the baby-oyster in this way gets a start that secures it a rapid growth—for it should be borne in mind that this is a critical period in the life of this diminutive thing. It is just now that it has to draw so largely on its small capital of vital resources, by directing the growth-force to the one object—a sure anchorage. Thus the secretions labor on the cementation of the lower valve to some solid object. Then comes the general shell-growth, which is very rapid, and at the same time the accelerated internal development; all which amounts to an entire reconstruction.

If, now, to this triple draft, occasioned by the anchoring, the shell-growth, and the development of the internal organs, one should add the necessity of procuring food in the usual amount, and by the usual means, would not the combined demand be exhaustive beyond the little creature's powers and resources? It should be observed, too, that now the food-necessity is more urgent than at any other period of its existence. It is also observable that the banquet prepared is ampler than at any other time. This is surely a striking instance in lowly quarters of a wise conservation of material and force. I am aware that this pad is differently disposed of by some naturalists; that it is said to drop off, and to be wasted; but, as I have witnessed a similar utilization of an otherwise useless member in other larval forms, I believe that observation will establish this view. And how remarkable this internal change, so rapidly progressing in the little oyster! It is a series of almost magic transformations. The eyes—if it had any—are gone. The external cilia, which served it for locomotive and breathing organs, disappear, and within appear true branchiæ, like those of its mother. A stomach, too, is now built up, and the labial fingers are provided. And that tiny, true heart appears, to the music of whose beating the little creature begins in earnest its life-work, as a perfect oyster, although hardly yet larger than the head of a pin. When a month old, it equals a large pea in size; at six months, it is an inch or more in length; at four years, it is large and amply ready for market, or even at three years, if the conditions of growth have been favorable.

THE OYSTER'S COMPANIONS.—For raising the seed, that is, the young oysters intended to be planted, a hard bottom, with plenty of shells, or objects for attachment of the spat, is desirable. But such a location would not be the place for growing and fattening the adult. A bottom with two or three inches of organic mud, and a hard pan beneath, and that in an estuary, or somewhere commanding a current, and receiving the river-flow, is the best. In this flocculent organic mud is much of the food of the oyster, and this food is in lively motion upon its surface. The algæ, or sea-weeds, often anchor to the shell, and adorn it with fronds of olive, and ruby, and the most exquisite emerald, while the sporules which rain from them are the true

manna of the oyster. The elegant red sponge, with its clustered lobes, almost like chalina, is sometimes found perched on the upper valve, like a great showy cockade. When, many years ago, before the Southern oyster was planted North, they used to take up the rich "naturals" around Bedloe's Island, this beautiful native sponge was often found in great tufts as large as a peck-measure. The oystermen called it "red-beard;" and often might be seen, at the door of an oyster-saloon in New York, a heap of these choice oysters, surmounted by a grand specimen of this red sponge. Even yet, at Craney Island, where the Elizabeth River and Hampton Roads meet, are acres of this pretty sponge. This sponge often renders a singular service to some fine old bivalve sinking with the weight of years into the rich organic ooze. It actually buoys it up, and rocks it, so that the under valve becomes white and bright with the gentle friction. In the crevices made by the lapping shoots on the upper valve, like tiles on a roof, are often found tiny univalves, sharing in the crumbs of the banquet on which the occupant of the great house feasts. We have often with

FIG. 3.—FLUSTRA FOLIACEA.—A Community of Bryozoa growing on Oysters and other Objects.

a penknife pried them out of their hiding-cracks, although much smaller than a grain of rice. Often, too, if examined closely, an oyster-shell may be found partly coated with a delicate net-work, as if some fine Valenciennes lace had been cemented thereon. These are the skeletal cells of the *Bryozoa*, or animate moss; for, though like moss somewhat, the little builders are living creatures, and, under the mi-

croscope, a bit of a live bryozoan-patch would look like a bed of living daisies, for these flower-forms are in lively motion in every part. Sometimes these communities of moss-like animals, such as are known under the generic name *Flustra*, build their structures up like plants, and literally embower the oyster in the most exquisite of fairy groves. The cut *Flustra foliacea*, Fig. 3, represents a European species. Its fronds, so to speak, are flat, and spatula-formed. With its gracefully-spreading lobes, like fronds, it has often been mistaken for an alga, or sea-plant. If you will only look closely at this cut of *Flustra foliacea*, Fig. 3, it will be seen to be full of minute cells. A look at Fig. 4, 1, will make this plainer, while in Fig. 5, 1, by greatly magnifying, the form of these little chambers in one of the species is shown. The naturalist, speaking of the entire establishment of one of these communities, calls it *Cœnœcium*, which means the common house of all the indi-

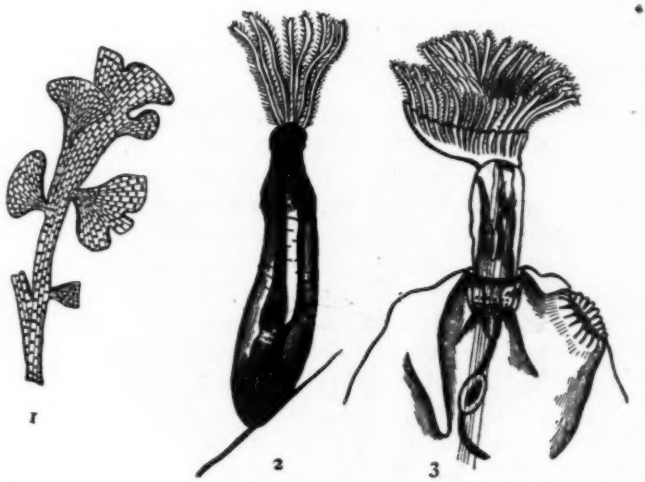

Fig. 4.—1. Fragment of Flustra Truncata, Natural Size; 2. A single polypide of *Valkeria* magnified to show its crown of tentacles; 3. A polypide of *Lophopus crystallinus*, a fresh-water polyzoon highly magnified, showing its horseshoe-shaped crown of tentacles.

viduals collectively; for each one of these little crypts, or chambers, is the exclusive apartment of one zooid, or individual member of the community. At the portal of this little crypt the occupant, when hungry, presents itself, and retires at its pleasure. When it does show itself, with tentacles spread, some idea of its individual beauty may be got by looking at the magnified tufts, like floral crowns, as shown in Figs. 4 and 5. When an entire community, or even a considerable part, is out airing, could one but see it, the sight would be very fine, for the smallest fragment in the microscope looks like a bed of daisies.

The oyster is often literally embowered in a substance that looks like diminutive trees. Its color varies from a reddish to a very pale brown, almost gray. The oystermen call it "gray-beard." Shore-

visitors often pick up tufts on the beach, and press them for sea-weeds. They are really the skeleton structures of a remarkable zoophyte, the Sertularia. We have an elegant species that grows upon the oyster, named *Sertularia argentea*, because it is often so white and glittering that it looks almost like silver. These I have found sometimes sixteen inches high, making the most exquisite, gossamer-tree. But it is no tree or plant proper. Their substance is chiefly lime. They might well be called sea-ferns. When magnified, living specimens show what might be mistaken for little buds. If the microscopist is both skillful and patient, he will see a little starry object like a flower push itself out of one of these buds, which is really its case in which it lives. It may be seen waving its little life-petals about, catching food. I have not forgotten the delight experienced when I found out this fact for myself. Let the reader dwell a moment on Fig. 6. The Sertularia buoys up the oysters, as does the red sponge. And one may readily conceive how the animalcules must swarm in these gossamer-like forests or groves, so that not only the zooids but the oyster also enjoys the richness of the fishing-ground.

Everybody, that has seen any dredging in Long Island Sound, knows that lumps of matter made up entirely of small calcareous tubes abound there. These tubes are often found adhering to the oyster; in fact, these animals build them on the oyster's shell. Its name is *Sabellaria vulgaris*, so named by Prof. Verrill. The constructor and occupant is a worm, but, for all that, a creature of surpassing beauty. In company with this, another little being builds a tubular home on the oyster. It is a small serpula or serpent-shell, and is called by Verrill, *Serpula dianthus*, the pink serpula, because, when the little dweller therein projects its tiny florets, in form and color they suggest the pink of our gardens. But there is projected by the side of that pretty little pink, a curious, funnel-shaped process, that looks like the tiniest kind of a trumpet. We have watched those pretty creatures with their floral heads out fishing. Let the slightest jar be given, and the little thing takes alarm and instantly withdraws into its stony tube: first the floral head disappears, then the trumpet-like structure is drawn in, which actually plugs up the entrance. All this will be understood from Fig. 7, which shows a serpula. The spirorbis here figured is really a serpula, a tube coiled into a spiral. I have never seen the spirorbis growing on the oyster-shell, but have taken it from sea-weeds and Bryozoa thence obtained.

This natural plug, or stopper, is not without a smack of drollery. At least it has always impressed me as having in it a taste of the intensely utilitarian. And this reminds me that, in all their beauty, there is also a savor of the comical in the Bryozoa. Please to look at that *Avicularium* in Fig. 5, 3. Is it not like the head of an eyeless bird? To see this "bird-head process" at work, one feels irresistibly that it is a real zooid, an individual among the Bryozoa, and Huxley

seems disposed to favor such a view. However, I believe all the proof as yet is on the side of its being a process, an organ, so to speak. Now, there are a good many of these bird-heads in the community, and very useful things they are. Let an animalcule too large for prey come fooling around these little Bryozoa, and one of the bird-heads will give it a nip such as to make a second one unnecessary. But these Bryozoa are in danger of being cloyed with dirt. These bird heads, like so many ants, pick off the annoyance. Is not all this

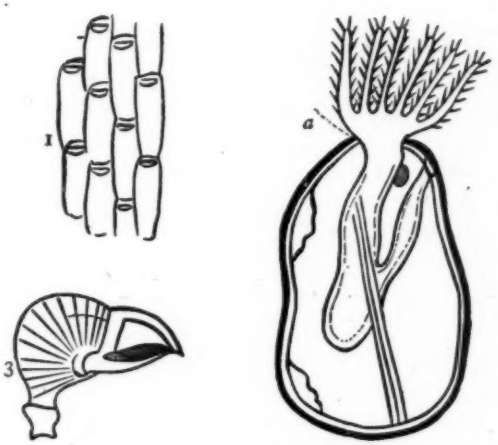

FIG. 5.—ANATOMY OF A BRYOZOON.—1, the skeleton cells; 2, diagram of an individual Bryozoon; *a*, the region of the mouth surmounted by a crown or tuft of tentacles; 3, an *avicularium*, or bird's-head process.

pretty? And it is quite ludicrous, too. And why should not Nature like a wee bit of drollery now and then?

If a pile of oysters be examined soon after leaving the water, especially if taken off a pretty clean bottom, a number of specks, about a quarter of an inch in width, may be seen adhering to the oyster, chiefly the upper side. They look like grease-spots, or small lumps of jelly. They are little sea-anemones, collapsed and dead. Alive in the water these are pretty objects, having a disk of a flower-form, with an orifice in the centre which opens into the animal's stomach, and which is really its mouth. (*See* Fig. 8). Such, then, is something of the oyster's environment. With such surroundings, so much of beauty, with a spice of Nature's humor, just enough to make this beauty true and pure, on the principle that a person is known by the company he keeps, the oyster might be set down as an individual of refined tastes.

Something should be said of the oyster's most intimate and familiar friend, a certain dapper little fellow in a scarlet jacket with trimmings of gold. From its size and form it is sometimes called the pea-crab; but, from the fact that it is only found in the oyster, it is gener-

ally known as the oyster-crab. Fishermen have insisted to me that it was the young of the edible crab. No naturalist, not even a tyro, could make this mistake. Naturalists have named this little crab, *Pinotheres ostreum*. Usually it is the female that one finds in the oyster. The male is much more rarely met with, and is smaller than the female, and of more sombre coloring. A dull brown is the predominant hue, though the legs are white. On the back is a figure remarkably like an anchor, done in white. But the history of the oyster-crab is imperfectly known. For aught that we have been able to learn, this pretty little crab is a harmless commensal. Whether it is always welcome by its entertainer we cannot say, but this is sure, Pinotheres has always been known as the oyster's bosom friend.

There is a story that General Washington was very fond of these oyster-crabs, and that, knowing this fact, a lady admirer, at whose house in New York the general was to dine, had an understanding with the different oystermen of the city, and their combined efforts got together half a pint of these diminutive crabs, which were served up and set before that eminent man, greatly to his surprise and delight. In the season, this little crab is readily obtained put up in half-pint bottles. Now that they have become a staple luxury in the city markets, why do not our epicures call them "Washington crabs?"

THE OYSTER'S ENEMIES.—The above must be set down as the rosy side of oyster-life, for they are a much-persecuted race. Though a sober people, always leading quiet lives, yet they seem to be regarded on all sides as possessing no rights that others are bound to respect. Let us make a visit to one of these orderly communities in Oysterdom known as a "planting-ground." We are seated in a boat, and, gliding through the phosphorescent sheen, soon near the oyster-bed. It is a moonlight night, about the close of summer. Hark! what singular sound is that? Boom! boom! boom! Almost sepulchral, and, strange to say, it comes up from beneath the waters. One would think they were Nereids' groans. The oystermen, whose capital lies invested there, hear it with sad forebodings of loss, which they cannot well sustain. It is one of a school of visitors who come with marauding purpose. The fishermen call it the big drum. This drum-fish is known among naturalists by the name *Pogonias chromis*. The acknowledged beat of this scamp is the Gulf Stream, from Cape Cod to Florida; and a terrible fellow is this Pogonias, for he is recorded as having attained the great weight of eighty pounds. One of twenty-five pounds would be but an ordinary affair. Their mouths are furnished with pavements of hard teeth, a little rounding on the top, and set together exactly as are the cobble-stones of the old city highways. The function of these dental pavements is to crunch the young oysters, which after being crushed are thus swallowed, shells and all. As these monsters come in shoals, they sometimes inflict serious damage on an oyster-bed. Not long ago, at Keyport, New Jersey, a visit

of this character cost the oyster-planters some $10,000. Said "an eminent naturalist," "No fish has teeth strong enough to crush oyster-shells." This is certainly a mistake. I believe that oystermen regard a three-year-old oyster as comparatively safe in this respect, and their apprehensions appertain to the younger beds.

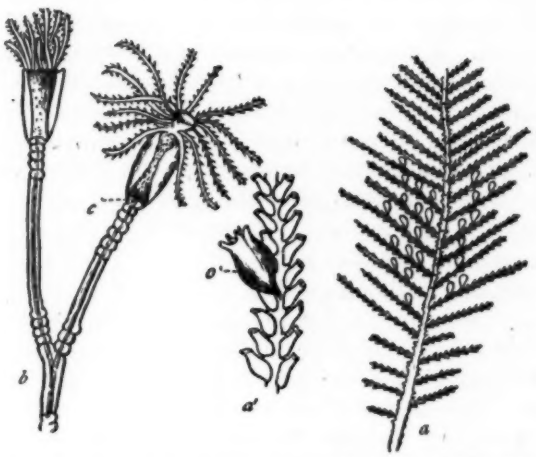

FIG. 6.—SERTULARIA PINNATA.—*a*, a fragment, natural size; *a'*, small portion magnified; *o*, shows the case of a male zooid; *b*, *Campanularia neglecta*, magnified.

At Long Branch, and in fact pretty much on the entire eastern seaboard, is often found the periwinkle, or great sea-snail (*Lunatia heros*). These are quite numerous. Oystermen have gravely told me that this animal kills the oyster. It has an operculum, or cover to the mouth of the shell, and they say that with this, as a knife, it opens the oyster. All this one might believe but for two difficulties: first, you could as easily open an oyster with the edge of a lady's visiting-card, for the operculum is of soft horn, and not thicker than a card; secondly, this Lunatia is not lunatic enough to try the experiment, as it is constitutionally a strict vegetarian, living upon the juicy sea-lettuce, and other algæ, so that on dietetic principles it has serious objections to the bivalve.

There is a small univalve, seldom much over an inch in length, which is justly chargeable with murderous assault on the oyster. The watermen very properly call it the drill. The latest name it has received from the conchologists is *Urosalpinx cinerea*. It is, however, more generally known among scientific men as *Buccinum cinereum*. It is a very pretty shell. The tongue is set with three rows of teeth like a file; it is, in fact, a tongue-file, or dental band, and is called by conchologists the lingual ribbon. (*See* Fig. 9.) This tongue-file is perfectly flexible, and with it the Buccinum drills a hole through the hard shell of the oyster. Owing to the fact that, when using this

dental ribbon, the broadly-spread pedal disk hides it, the exact method of the operation is concealed. Having with the utmost care witnessed a number of times the creature in the burglarious act, I give the following as my view of the case: With its fleshy disk, called the foot, it secures by adhesion a firm hold on the upper part of the oyster's shell. The dental ribbon is next brought to a curve, and one point of this curve on its convex side is brought to bear directly on the desired spot. At this point the teeth are set perpendicularly, and the curve, resting at this point as on a drill, is made to rotate one circle, or nearly so, when the rotation is reversed; and so the movements are alternated, until, after long and patient labor, a perforation is accomplished. This alternating movement, I think, must act favorably on the teeth, tending to keep them sharp. To understand the precise movement, let the reader crook his forefinger, and, inserting the knuckle in the palm of the opposite hand, give to it, by the action of the wrist, the sort of rotation described. The hole thus effected by the drill is hardly so much as a line in diameter. It is very neatly countersunk. The hole finished, the little burglar inserts its siphon or sucking-tube, and thus feeds upon the occupant of the house into which it has effected a forced entrance. To a mechanic's eye there is something positively beautiful in the symmetry of the bore thus effected—it is so "true;" he could not do it better himself, even with his superior tools and intelligence.

Oystermen also complain of ravages perpetrated by the great conch. But there are two of these conchs, widely distinguished by naturalists. One of them has the upper edge of the whirls ornamented with a projection, with bosses at uniform intervals: this is the keeled conch, and is called, by Conrad, *Fulgur carica*. The other one has a canal or groove running round the shell, on the top of the whirls: this is the grooved conch, and it has lately been named, by Gill, *Sycotypus canaliculatus*. The oystermen say that these conchs "rasp the nib of the oysters;" and with their large tongue-files this is not hard to do. It is certainly going a great way for an analogous case; but I have examined numbers of the first-created oysters, fossil oysters, in the New Jersey Cretaceous formation, and have found not a few among them which had received precisely that treatment from certain ancient carnivorous gasteropods.

But the most insidious foe to the life and peace of the poor oyster is the star-fish. The American species, which does the mischief, is the green star-fish (*Asterias arenicola*). The species obnoxious to the European oyster is the red star-fish (*Asterias rubens*). (*See* Fig. 10.) The sea-star does not like water that is too brackish; that is, it loves salt-water. Whenever the Shrewsbury River is affected by the breaking in of the sea, there is danger for its celebrated oysters. On several occasions, at such times, the star-fishes have come up in great numbers, and utterly destroyed the bivalves. At one time so great were

their numbers, that they were thrown up on the shore in large, loathsome, squirming balls. Says Verrill, "In one instance within a few years, at Westport, Connecticut, they destroyed about 2,000 bushels of oysters, occupying beds about twenty acres in extent, in a few weeks, during the absence of the proprietor."

It is curious to read the silly stories that are told in the name of Natural History. There is one that says that the star-fish puts its fingers or rays into the oyster's shell, and helps itself. From every point of consideration the thing is ridiculously impossible. A more sober judgment is that given by some naturalists, namely, that the sea-star protrudes its great sac-like stomach, and envelops to a great extent the oyster therein, and so leisurely digests the mollusk out of its unopened shell, much as a codfish does the shells it swallows.

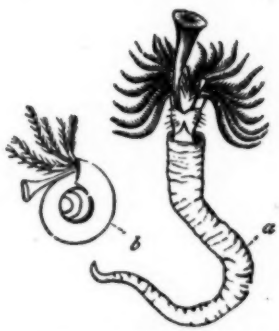

FIG. 7.—TUBICOLA.—*a*, *Serpula contortuplicata*; *b*, *Spirorbis communis*.

After having seen young star-fishes eat small specimens (that is, such as were suited to their size) of oysters, mussels, and scollops, which I have fed to them in an aquarium, I give the following as based on a number of observations: Having brought the oval, or stomach orifice, exactly opposite the nib of the oyster, the star embraces the bivalve with its five flexible rays, aided by the hundreds of sucking-disks on the tiny feet. Thus positioned, the star-fish clings firmly, but keeps itself quite still, and waits very patiently. After a while, the instinct of the oyster will be at fault, and it will open, as if no enemy were near. At this moment, as it seems to me, is injected from the oral orifice of the star a baleful "sidereal blast." It is a something that paralyzes the mollusk; because, from that moment the valves of the oyster are opened to their full extent, and the hold of the flexible rays is relaxed. Instantly a singular variation of the performance sets in. The rays are withdrawn and set back to back—the stomach is protruded, and the doubled-up star intrudes itself into the oyster, the evicted stomach leading the way in the movement, and absorbing its victim. If the famous "India-rubber man" could throw backward his arms, legs, and head, and in this position could then infuse him-

self, stomach-first, into a partially-opened writing-desk, he would rival this feat of the sea-star, without the villainy of injecting chloroform through the key-hole.

But the oyster race has one foe more formidable than all the rest—one who invades their ancient waters with iron implements and hungry fleets—who brings to his service the appliances of a high intelligence, and the impulsion of an imperious necessity—who, after the strictest rulings of the old barbaric cannibals, assigns the adult captives to immediate immolation, and reserves the young to be grown and fed for a future feast. And everybody eats the poor oyster—

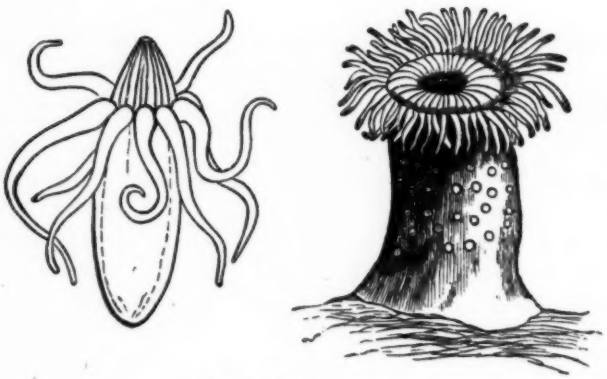

FIG. 8.—SEA-ANEMONES.

prince and peasant—the healthy and the sick; even he who is paying the penalty of long defiance to a stern physical law, and to whom all food is suggestive of torture, thinks he might stand an oyster or two. The rollicking student, brimming full of frolic and swagger, emerging from his day's course on the humanities, fancies that oysters make a good dessert after such dry pabulum. In fact, he holds the bivalves in so high esteem that he informs "Chum," sentimentally, of course, that he thinks oysters should be called *pabula amoris*, and proposes a dozen each on the half-shell. So the saloon-man prepares for the immolation. With the implement of his calling he taps at the passage-way, "The gate's ajar." Treachery! The iron enters the soul! Chum takes the initiative. The mollusk approaches the lips—and—it is gone! There is a gleam in Chum's eye—a flash ecstatic; it is the light of genius satisfied. "Tom, it is the elixir of the gods solidified! How it went down like a chunk of bliss! *Facilis descensus Averni.*"

It is a pity that candor should compel one to seem to spoil this fine Roman sentiment by quoting Roman practice. But we cannot cover up history; and we are the less willing to do so, because we are about to cite transactions that will prove the great wrongs suffered by Ostrea, for so these Romans called our oyster. The chroniclers tell that

the Emperor Vitellius could eat a thousand of these bivalves at a meal. What vitals must this Vitellius have had! Who would dare undertake to victual such a glutton as that? It is said of that gentle wag, Charles Lamb, that, on a certain occasion, the omnibus in which he rode was stopped by a man, who poked in his head and bluffly asked, "All full in there?" To which Lamb meekly made response, "I don't know how it is with the rest—but that last piece of oyster-pie did the business for me!" But this Vitellius was not so easily done

FIG. 9.—FRAGMENT OF THE TONGUE-FILE, OR LINGUAL RIBBON, OF THE WHELK (*Buccinum undatum*), MAGNIFIED.

for as that comes to. Having engulfed his fill of these ostrean innocents, this royal gourmand would open the sluice-gate of his kingly maw, and cause a slave to tickle the fauces with a peacock's feather. This, acting as an elevator, effected a full discharge of the beastly cargo of that carnal vessel. This done, that ostreaceous appetite would load up afresh. Would not the evertible stomach of a star-fish have been an inestimable blessing to that imperial beast?

DIETETICS OF THE OYSTER.—Are oysters good to eat? Said Montaigne, "To be subject to colic, or deny one's self oysters, presents two evils to choose from." This is very fine for Montaigne, but it is a libel for all that. Besides, he was a sickly man at best of times. Says Reveille-Paris: "There is no alimentary substance, not even excepting bread, which does not produce indigestion under given circumstances, but oysters never. We may eat them to-day, to-morrow, eat them always, and in profusion, without fear of indigestion." It is said that the first Napoleon always ate oysters on the eve of his great battles, if they could be got. Says Figuier: "The oyster may thus be said to be the palm and glory of the table. It is considered the very perfection of digestive aliment. . . . The small proportion of nutritive matter explains the extreme digestibility of the oyster." It "is nothing more than water slightly gelatinized." But, if we would have authority the most recent, and thoroughly trustworthy, let us go to that little book in the "International Scientific Series," "Foods," by Edward Smith, M. D. Here we have the dictum of the physiologist: "The oyster is not a food of high nutritive value, but is nevertheless useful to the sick, while its delicacy of flavor leads to its selection when other foods are rejected. The more usual mode is to eat it when uncooked; and it is very doubtful whether cooking increases its digestibility. It is, however, possible that the flavor of scalloped may be preferred to that of the raw oysters, or that the vinegar which is usually eaten with the latter may be disliked, or may disagree with the stomach, but, with

such exceptions, the usual method of eating them raw is to be preferred" (page 116).

Americans, I believe, are the only people who eat the so-called soft-shell crabs; that is, crabs at the time of having cast the skin. It is not at all probable that, at such a time, the animal is wholesome food. And so with oysters, during the spawning-season, it is wiser to abstain, for the reason that one is not sure that the oysters we are eating then are not in a spawning state. In its normal condition the oyster is excellent food; and, if we assign it its rank among the shell-fish, it will be, without dispute, the queen of the bivalves.

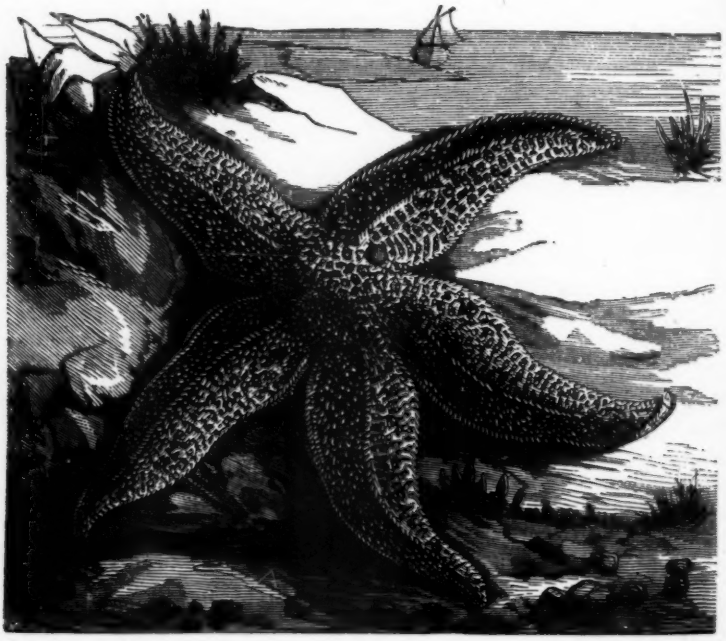

FIG. 10.—ASTERIAS RUBENS, A EUROPEAN SEA-STAR, OR STAR-FISH.

SOME FACTS, GEOGRAPHICAL AND ETHNOLOGICAL.—Says Figuier, Virginia has 2,000,000 acres of oyster-beds. In many places they grow so thickly that they make immense mounds in the water, the lower oysters being killed by those above. Even mouths of the sea have been closed by them, says Dr. Smith. Certainly in this particular the wealth of Virginia and Maryland is immense. In former times all the suitable waters of New York and New Jersey abounded in native oysters. There are those yet living who remember the custom of the farmers to go with their wagons to the shore at or near Keyport, New Jersey, to gather "natural" oysters. There is a curious old map in existence which will, we predict, become famous as an authority in the appeals of State diplomacy. It is dedicated to Governor Moore,

of the province of New York, by its author, who signs himself "B. Ratzer, Siuv'r in His Majestie's 60th American Reg't." It is a map of the city of New York, and it gives the waters of the entire harbor, with their soundings. Its date is 1767. A large tract of water is marked "THE OYSTER-BANKS." In that area of what was then fine native oysters is now the vast patch of "made-land," laid down by the filling in of the city's refuse, by the New Jersey Central Railroad, and which matter is now in litigation. The time was when the entire waters west of the channel, beginning south of Jersey City, and surrounding Ellis and Bedloe's Islands and Robbins's Reef, and a little way beyond Constable's Point, up the Kill Von Kull, altogether some six miles in a straight line, was a rich bank of native oysters, and supposed to be inexhaustible. It can hardly be questioned that, when the European settled here, that which is now the eastern coast-line of the United States contained, by several times, more of these edible bivalves than did all the rest of the world. The very shells left inland in many places, by the aboriginal oyster-eaters, make mounds of vast extent, in some instances thirty feet high. At Fernandina, and other places in Florida, they were used as forts in the late war. As to their antiquity, there can be no doubt that oysters were eaten there thousands of years ago.

Recent ethnological investigations indicate, at least, the strange fact that the people who began those shell-heaps antedated the supposed autocthones of the American Indian. Their bones have been discovered, and they show an osteology not known among any of the red-men of to-day, namely, a flattening of the tibia, or shin-bones. The relics of the great mounds have shown the same fact; and so marked is this, that the name *platycnemic*, or flat-shinned, is proposed for this ante-historic race. Again, the unpleasant fact is also indicated that these same ancient oyster-eaters were cannibals. And those heaps of oyster-shells on the land, in which are mixed relics of the ancient races, extend from Florida to Maine. They are found on islands in Casco Bay. But the oyster is not an inhabitant of these parts to-day. In fact, it is a sort of fossil; so that some great geological change has taken place on our coast since those times in the long ago. This surely points to a great antiquity of these autocthonic oyster-eating men. And the several facts just enumerated would indicate the extraordinary prevalence of this bivalve on our Eastern coast. The most ancient name of Britain is Albion, with evident allusion to its white cliffs. If this truthfully characterized the Druid-Land, it surely would not have been less appropriate, nor less poetical, had the first adventurer named this Occident shore the Oyster-Land.

So, then, how potent has been the influence of the oyster in the industries, and morals, and convivialities of the ancient and the modern man!

SOME SUPERSTITIONS OF HYDROPHOBIA.

By CHARLES P. RUSSELL, M. D.

THE reign of Sirius is over, and the dread of hydrophobia has ceased to agitate the public mind. At this auspicious season of the year we may approach the subject with cool premeditation, and deal with it in our own way. No longer do we regard our canine associates with a sort of indefinable apprehension. Our Spitz "Prince" pursues with savage intent the obnoxious house-fly, without exciting any suspicion of "snapping at imaginary objects in the air." His appetite is capricious, and we merely sympathize with him as a fellow-sufferer from dyspepsia. He bites a part where crawls the occult flea, without having to undergo a critical examination for a "point of injury." He retires in dim seclusion under the sofa, and indulges in reverie—disagreeable reminiscences of the past, grim contemplations of the present, and perhaps gloomy anticipations of the future—without having his moroseness misinterpreted. He becomes uneasy and fidgety, even peevish and ugly at times—what then?—like master like dog, he serves to illustrate our human moods. Occasionally he displays toward us an exaggerated degree of affection almost unaccountable in any Prince of mature age; but this is in the early morning, and the odor of his favorite liver ascends from the kitchen; even his blandishments, alas! are sometimes selfish. He is now permitted to run through the street without a muzzle, and to consort with the *οἱ πολλοι*—"the great unwashed"—of his tribe; which affiliation he thoroughly enjoys, albeit a dog of most aristocratic pedigree—remembering, possibly, that both his descent and theirs are by many naturalists derived from a common and somewhat disreputable ancestor named Wolf. In fact, the dog-days being past, his follies, his faults, all his vagaries, seem natural as ever. How is it, we now ask ourselves, that this faithful servant and friend should have been under such a cloud during all the bright summer? Why, as Mr. Mayo has remarked, should he be regarded at that particular season as being subject to "a sort of dog-lunacy, having the same relation to Sirius that insanity has to the moon—which, indeed, in another sense, is probably true?" The answer may be found in that peculiarity of human nature which clings fast to traditions and superstitions, and will most probably always do so until man ceases to be human. It is the province of science, however, to battle with these familiar foes, and to at least surround with invincible lines the almost impregnable positions in which Time has intrenched them among the credulous and ignorant.

The mysterious influence of the "dog-days" upon the canine race is an opinion of the greatest antiquity, dating back apparently to Annubis, the dog-form of the Egyptian Apollo, whose appearance in the

heavens was a premonition of impending danger. It probably also had some connection with the Κῠνοφόντις ἑορτή, a festival of the Argives marked by the destruction of many dogs. In the "Iliad," Homer mentions Orion's dog as affecting human health disastrously. Pausanias, in his "Travels in Greece," alluding to the story of Actæon's destruction by his own hounds, was inclined to attribute the myth to the circumstance that the season had caused the pack of the famous hunter to run mad. Pliny remarks, in his "Historia Naturalis," that "canine madness is fatal to man during the heat of Sirius, and proves so in consequence of those who are bitten having a deadly horror of water. For such reason, during the thirty days that this star exerts its influence, we try to prevent the disease by mixing dung from the poultry-yard with the dog's food, or else, if he is already attacked with the disease, by giving him hellebore." From the time of Pliny until quite recently the development of rabies by summer heat has been accepted as a fact among scientific men, and the idea has become too deeply rooted in the popular mind to be easily eradicated. Only within the present century has it been proved conclusively by critical inquiry that no season of the year is specially concerned in the production of this formidable affection. Hence the absurdity of legislative enactments designed as precautionary measures against hydrophobia, and operative only during the summer months.

Our old and esteemed friend Pliny is responsible for several other very remarkable statements with regard to the dog. He asserts gravely that dogs will run from any one having a dog's heart about him, and will never bark at a person who carries a dog's tongue in his shoe under the great toe, or the tail of a weasel which has been liberated after being deprived of that appendage. Among various absurd preventive means which he recommends, as efficacious in the case of a person bitten by a mad dog, is, to insert into the wound ashes of hairs from the tail of the animal which inflicted the injury. Hence the half-sick reveler, as he imbibes his morning potation, assures himself of its curative effect in the remark that he is taking "a hair of the dog that bit him."

The same author informs us of a belief common among the Romans, that a dog which laps the milk of a woman who has had a male child will never become rabid.

Another singular tradition, handed down from remote antiquity, but popularized by Pliny, is the idea that beneath the dog's tongue is situated a worm whose existence encourages the development of hydrophobia, and whose extirpation in puppyhood is an infallible preventive of the disease. He thus alludes to it: "There is in the dog's tongue a small worm known as 'lytta' among the Greeks. If this be removed from the animal while a pup, it will never become rabid or lose its appetite. This worm, after being carried thrice around a fire, is given to persons who have been bitten by a rabid dog, to prevent

their going mad." There is a curious correspondence between this recommendation of Pliny's and the following recipe for the "tear of a mad hound," found in an old Anglo-Saxon leech-book, written about the commencement of the eleventh century, entitled "Medicina de Quadrupedibus:" "Take the worms (thymas) which be under a mad hound's tongue (under thede hundes cunzan), snip them away, lead them round about a fig-tree, give them to him who hath been rent; he will soon be whole."

Allusion is made to this worm in a work called the "Kynosophian," supposed by some to have been written by Phæmon, while others attribute it to Demetrius Pepagomenos, a Greek writer residing at Constantinople in the twelfth century. In this book it is asserted that underneath the dog's tongue is a little body like a white worm, which must be quickly destroyed ere it increase and invade the whole throat. In the sixteenth century, Fracastorius, in a poem styled "Alcou, sive de cura Canum Venaticorum," refers to it in the following words: "Vulnificus *vermis* suffunditque ora veneno."

In more modern times, the Germans generally believed in it, terming it the *Tollwurm*, or *worm of madness*. So popular was the superstition, that, in the middle of the last century, there existed in Prussia an ordinance requiring all owners of dogs to submit them to this mutilation. The ordinance was rendered more specific by a royal decree of February 20, 1767, establishing a regular corps of operators, whose duty consisted in visiting semi-annually all houses containing dogs, "worming" every animal, and furnishing the master thereof with a certificate to that effect. The edict prescribed, likewise, that every dog should be so treated before it had become six months old, and persons violating the law were condemned to pay a fine of fifty Prussian crowns, or, in default thereof, to suffer an imprisonment of one month. In 1786 a similar law prevailed in Hanover. This so-called worm was explained by some to be a vein, whose absence in a dog menaced by hydrophobia leads to engorgement of the throat and immediate asphyxia. It was regarded by Morgagni and Heydecker, after careful examination, as a spiral tendinous arrangement peculiar to the canine race, having some connection with the genio-hyo-glossus muscle, and serving to facilitate the act of lapping. Other authorities, however, deemed it to be the duct of the submaxillary gland, and others still maintained that it was merely the frenum linguæ. The English author, Fothergill, in his celebrated treatise on Hydrophobia, remarked that nothing was definitely settled relative to the utility of the operation, but that the whitish vermiform substance thus removed was nothing else, it might be presumed, than the canal forming a portion of the salivary apparatus, whose destruction might possibly exercise some influence upon the secretion, in diminishing, to a certain, extent, the liquid which transmits the virus.

The whole theory, however, was substantially demolished in 1786,

in the very country where it was most in vogue. A rabid dog, near the village of Trieglitz, Prussia, bit a shepherd's dog, which was shortly afterward seized with rabies, and in turn communicated it to several cows. Both of these dogs were proved, by authentic certificates, to have undergone, when pups, the prescribed operation. The sanitary physicians of the district assembled to investigate the subject, and numerous instances were brought to their notice of hydrophobia having been imparted to both animals and men by dogs whose Tollwurms had been extirpated in the most approved manner. These facts led to the suppression of the corps of operators. Subsequently the authorities of the province of Detmold convoked a similar commission of investigation, the result of whose inquiries fully confirmed the conclusions previously reached.

This idea never obtained much credence among the English. Dr. Samuel Johnson spoke of the reputed worm in his expressive manner as "a substance—nobody knows what, extracted—nobody knows why."

According to a report of Dr. Armand to the Paris Academy of Sciences, the same practice still exists in Thrace, and it is described by Auzias Turenne, in the "Receuil de Médecine" for 1869, as then prevailing in Turkey and Moldo-Wallachia. Fleming states that it is quite common in Roumania, and Ramon de Sagra alludes to it as being popular in Spain. It prevails to some extent in our own country, especially in the South.

Columella, a contemporary of Pliny, in a work entitled "De Re Rustica," informs us that in his time it was believed among shepherds that, if, on the fortieth day after a pup's birth, the last bone of the tail be bitten off, the sinew will follow with it; after which the tail will cease growing, and the animal will remain secure from madness. This brutal mutilation is still sometimes practised by dog-fanciers, particularly in England, where the Royal Society for the Prevention of Cruelty to Animals have obtained several convictions against those resorting to it.

The ancients ascribed peculiar virtues to a variety of stone called *ammonis cornu*, which was supposed to possess the property of extracting the virus from wounds inflicted by mad dogs or venomous reptiles. Pliny alludes to it under the above name, and it has since received the appellation *ammonite*, both terms referring to its resemblance in shape to the horns which surrounded the head of Jupiter Ammon. It has also, in more modern times, been popularly known as the *mad-stone* and the *snake-stone*. Scientifically speaking, it is the fossil petrifaction of an extinct mollusk closely resembling the nautilus, having a spiral, symmetrical, and chambered shell, varying in size from that of a small bean to that of a large cart-wheel. In the East Indies and China it has for ages enjoyed the reputation mentioned.

In the fourth volume of the *Medical Repository*, an old journal published in this city in the beginning of the present century, may be found a communication from a Virginia gentleman, entitled "The Chinese Snake-stone, and its Operation as an Antidote to Poison." This remarkable stone, it appears, was brought from Bombay in 1740, and a portion of it subsequently came into the hands of Rev. Mr. Lewis Chaustien, of Frederick County, who employed it in cases of snake and dog bites. The writer describes how, his little daughter having been bitten by a mad dog, he was induced to carry her to Mr. Chaustien in order to obtain for her the benefit of his remedy. Having been informed that the stone, which was in three pieces, would adhere to no wound except one inflicted by a serpent or a mad dog, he tried the experiment of placing a piece upon two scratches on his child's body occasioned by a recent fall, but it immediately dropped off. On being applied, however, to the dog-bite, it at once took hold like a leech, and continued to stick for eight hours; and the other two pieces adhered successively an equal length of time before they fell off. They were then immersed in hot water, when, in a short time, a number of small bubbles began to rise, and a scum, like oil of a greenish-yellow color, soon covered the surface. The pieces were afterward dried in warm ashes. Mr. Chaustien exhibited a certificate which had accompanied the stone from Bombay, and which attested its efficacy in extracting venom from the bites of all poisonous animals. Another piece was in the possession of a Mr. Joseph Fredd, of Loudon County, Va. These wonderful stones doubtless still exist with virtues unimpaired—a profitable inheritance for those whose privilege it is to bestow their inestimable boon upon credulous humanity.

One of the most ancient measures employed in the case of a dog suspected of hydrophobia was, a prolonged sousing in cold water, which treatment, however, was not confined to animals, but was extended to persons whom they had bitten. Euripides, the Greek tragic poet, was said to have been thus preserved from hydrophobia. Even the celebrated and sagacious physician Celsus appears to have had confidence in the process, as he thus describes it: "The only remedy is to cast the patient unexpectedly into a pond, and, if he has no knowledge of swimming, to allow him to sink, in order that he may drink, and to raise and again depress him, so that, although unwillingly, he may be satiated with water."

In more modern days, Van Helmont gives the following quaint description of the same formidable method, as employed in his time: "There is a castle situated by the sea-side, four leagues from Ghent, which they call Cataracta. I saw a ship passing by it, and therein an old man, naked, bound with cords, having a weight on his feet; under his armpits he was encompassed with a girdle, wherewith he was bound to the sail-yard. I asked what they meant by that spectacle. One of the mariners said that the old man was an hydro-

phobid, or had the disease causing the fear of water, and had lately been bitten by a mad dog. I asked toward what part of the sea they wished to carry him. Did they intend his death? 'Nay, rather,' said the mariner, 'he shall presently return whole; and such is the blessing of the sea, that such a kind of madness it will presently cure.' I offered them some money to take me along with them as a companion and witness. When we had sailed about an Italian mile, the mariners did open a hole in the bottom, whereby the whole ship was almost sunk, even to the brim; indeed, they used the brine to recoct Spanish salt. And when, as that hole was now again exactly shut, two men, withdrawing the end of the sail-yard, lifted up the top thereof, and bore the old man on high; but thence they let him down headlong into the sea; and he was under the water about the space of a *miserere*, whom afterward they twice more plunged, about the space of an *angelical salutation*. But they then placed him on a smooth vessel, with his back upward, covered with a short cloak. I did think that he was dead; but the mariners derided my fear, for, his bonds being loosened, he began to cast up all the brine which he had breathed in, and presently he revived. He was a cooper, of Ghent, and, being thenceforth freed from his madness, lived safe and sound. Also the mariners did relate that the Dutch, by a raw herring salted, applied to the bite of a mad dog for three days' space and renewed, do take away all fear of madness. When this has been neglected, at least by the beheld manner of plunging they are all cured."

Fleming states that in Syria, at the present day, when a person is affected with hydrophobia, he is confined in a dark room, great care being taken to keep him tranquil, and prevent his seeing any red-colored object; and, if he thus survives for a certain period, he is cast from an eminence into the sea. This treatment would appear almost as effectual as another plan once pursued with hydrophobic patients, viz., smothering them between feather-beds.

A mere enumeration of all the absurd devices and medicaments employed from time immemorial to prevent or cure hydrophobia, would fill many pages. Charms, incantations, amulets, and mysterious religious rites, have had a large share in such preservative measures. One of the more modern and most remarkable superstitions connected with this subject is the reputed cure of hydrophobia by a pilgrimage to the shrine of St. Hubert, in the Ardennes—a custom prevailing even now in Belgium, and dating back to the ninth century. According to the legend, the stole of St. Hubert, by which the miracle is accomplished, was brought from heaven by an angel, who presented it to the saint while he was praying at the tomb of St. Peter, in Rome. At the same time he received also a golden key from St. Peter, by which he became endowed with a special power over evil spirits. Van Helmont thus alludes to the miraculous powers

of this vestment: "Our good Catholics, despairing of relief from the faculty, repair to St. Hubert, at whose shrine, by virtue of certain ceremonies, they are cured; but it is worthy of remark that, if these ceremonies are not strictly observed, the latent rabies immediately breaks out, and they become irrevocably hydrophobic. There is a vestment of St. Hubert's which is preserved in a chest secured by six locks, the keys of which are kept by the six different vergers. For these fourscore years past they have been continually cutting off pieces from this holy vestment; nevertheless, it remains to this day perfectly entire! Now, it is impossible that there should be any imposture in the case; for they have never been able to discover whether this miraculous robe be of linen, woolen, or of silk; consequently it cannot be annually renewed. They cut off a piece of the robe and incarnate a thread between the skin of the patient's forehead. Hence another miracle—for a person thus cured becomes possessed of a power to postpone the hydrophobia during forty days in any of his acquaintance who, after being bitten, may not have leisure immediately to visit St. Hubert; on the condition, however, that, if they exceed the forty days ever so little, without applying for a prorogation of the term, they go mad irrevocably."

A rubric of the regulations to be observed by the patients, in order that the miracle might succeed, was printed in 1671. It contained a long catalogue of ridiculous observances and ceremonies, all of which, however, were in the same year condemned by the Sorbonne as "superstitious." That this practice continues, notwithstanding the oracular declaration of that famous theological establishment, may be inferred from the following circumstance, related by M. Stanislaus Prioux, in his "Vie de Saint Hubert:" "At the time when rabies had spread the utmost terror over the greater portion of the northern countries (about two years ago, in 1851), I knew an old man at Brussels, who, in his youth, had undergone the ordeal prescribed by St. Hubert, and who yet carried on his forehead the precious cicatrix. He assured me he had saved the lives of several people by granting them delays, while others bitten at the same time by the mad animals died."

According to Fleming, who quotes from Dudley Costello's "Tour through the Valley of the Meuse," what are called "the keys of St. Hubert" consist of an iron heated red-hot, and applied to animals bitten by mad dogs. It appears never to have borne the form of a key; for, in the town of St. Hubert itself the amulet was an iron ring inserted in the wall of one of the houses in the principal street. It no longer exists, though the belief in the potency of St. Hubert is, among the peasantry, as strong as ever. In other places, where this saint is especially venerated, the form of the exorcising instrument in no way resembles the key given by St. Peter. At Liège, it is also an iron ring, and at Utrecht an iron cross.

Among people more or less uncivilized, there prevail some curious notions with regard to hydrophobia. In the mountainous districts of Roumania, where the disease is common among wolves and dogs, the peasantry believe that birds of prey, as eagles, hawks, vultures, etc., fall dead from an aërial elevation never reached by other creatures, and are devoured by wolves; these latter thus contract rabies, transmit it to the shepherd-dogs, and they in turn communicate it to cattle and human beings simply by infecting the atmosphere with emanations from their diseased bodies. According to Burton (in his "Pilgrimage to Medinah and Mecca"), the tribes of El-Hejaz—a district of Arabia on the Red Sea—imagine that a bit of meat falls from the sky and renders mad any person eating it. They also recognize the fact of the communicability of hydrophobia from dogs. Burton says: "I was assured by respectable persons that, when a man is bitten, they shut him up, with food, in a solitary chamber for four days, and, if, at the end of that time, he still howls like a dog, they expel the *ghul* (devil) from him by pouring over him boiling water mixed with ashes —a certain cure, I can readily believe."

Sir Samuel Baker, while exploring the Nile tributaries of Abyssinia in 1862, found rabies quite prevalent in those regions. He relates how he was one night disturbed by a tremendous tumult, and light filling the air, and yelping of dogs. He went out and ran toward a blazing hut. "As I approached, first one, and then another dog ran screaming from the flames, until a regular pack of about twenty scorched animals appeared in quick succession, all half mad with fright and fire. I was informed that hydrophobia was very prevalent in the country, and that the certain preventive from that frightful malady was to make all the dogs of the village pass through the fire. Accordingly, an old hut had been filled with straw and fired, after which each dog was brought by its owner and thrown into the flames."

Fleming, while quartered with the British Army of Occupation at Tien-tsin, near Peking, China, in 1861, was assured on the best authority that, in some portions of the Flowery Land, it is the universal belief that a man affected with hydrophobia is *enceinté*, and that he is so distressed, and ultimately perishes, because he cannot be delivered!

Closely connected with outbreaks of lupine rabies, of which we have authentic accounts as early as the thirteenth century, was the remarkable superstition of the middle ages termed *lycanthropia*—a belief that human beings were temporarily transformed into wolves (or "were-wolves" as they were called), in order to satisfy an unnatural craving for human blood. It is well known that the wolf, when rabid, exhibits a peculiar change of habit and character. It quits its customary haunts in the forest recesses, and displays no fear or hesitancy in entering towns and villages, where it boldly encounters dogs, men, and other creatures, attacking them furiously, biting and tearing them, and then continuing its dreadful course of destruction. Brera

relates that at Crema, Italy, in 1804, a mad wolf descended from the mountains and bit not only a vast number of animals, but thirteen persons besides, of whom nine perished of hydrophobia. This peculiar audacity of the rabid wolf, and the fact that a human being suffering from the disease often imagines himself personally identified in some manner with the animal that bit him, were doubtless largely concerned in the maintenance of this superstition at a period when, as Lecky observes, the air was surcharged with the supernatural. But, in fact, this fable may be traced back to mythological ages, and the existence of the "were-wolf" has been attested by Herodotus, Pliny, Strabo, Virgil, Ovid, and other ancient authors. Most of us remember the story recounted in Ovid's "Metamorphoses," of Lycaon, King of Arcadia, who entertained Jupiter with human flesh, in order to prove his omniscience, and was punished by having all of his sons, save one, and himself, transformed into wolves:

> "In vain he attempted to speak; from that very instant
> His jaws were bespattered with foam, and he only thirsted
> For blood as he ranged among flocks and panted for slaughter."

There are probably few countries in the world where some form of this superstition has not existed, but it has raged especially in places infested with wolves—in the Jura, in Russia, in Ireland (where, according to Camden, the inhabitants of Ossory were said to become wolves every seven years), in the wooded districts of Germany, France, Italy, Greece, and Turkey—regions where lupine madness has been particularly prevalent. Olaus Magnus, a writer of the middle ages, relates that in Prussia, Livonia, and Lithuania, although the inhabitants suffered much from the ravages of wolves among their cattle, they regarded such inroads as of little consequence compared with the ferocious attacks of were-wolves. He says, "On the feast of the Nativity of Christ, at night, such a multitude of wolves transformed from men gathered together in a certain spot, arranged among themselves, and then spread to range with wondrous ferocity against human beings and those animals which are not wild." Fincelius informs us that, in 1542, there were such a great number of were-wolves about Constantinople that a special expedition was organized against them, and the sultan, accompanied by his guard, left the city and slew one hundred and fifty. A French judge, named Boguet, about the end of the sixteenth century, devoted himself especially to lycanthropes, of whom he burnt a multitude, and afterward wrote a treatise on the subject.

Among the stupid popular ideas prevailing at the present time with regard to a mad dog is the belief that persons, who may have been bitten by the animal a long time previously and when it was healthy, are in danger of developing hydrophobia upon its subsequent appearance in the dog. This notion would seem almost too ridiculous

to mention, were it not so common, that a dog who bites a person maliciously is almost invariably killed, with the sole intention of rendering the human being secure from hydrophobia. A little reflection should convince those who entertain this foolish superstition, that, by killing the animal, they are depriving themselves of the only means of certainty as to its actual condition; for, if in the first vague stages of rabies, it must exhibit pronounced symptoms within a very few days, whereas, if it remain healthy, by no possibility can the person bitten suffer other consequences than those ensuing from an ordinary wound.

PHYSIOLOGICAL BASIS OF MENTAL CULTURE.[1]

By NATHAN ALLEN, M.D., LL.D.

IN the advancing knowledge of physiology it has been discovered that all mental culture should be based upon the brain—that education should be pursued in harmony with the laws of life and health, and that, where these are violated, the advantages of the former afford poor compensation. Formerly no attention, or scarcely any, was paid by school boards and teachers, in the matter of education, to the condition of the body or the development of the brain, and even at the present day very little is paid them, compared with what should be given to those great physical laws which underlie all mental culture. The lives of a multitude of children and youth are sacrificed every year in this Commonwealth by violating the laws of physiology and hygiene, through mistaken or wrong methods of mental training; besides, the constitution and health of a multitude of others are thus impaired or broken down for life. Nowhere else in society is a radical reform needed more than in our educational systems. Inasmuch as the laws of the body lie at the foundation of all proper culture, they should receive the first consideration. But, in educating the boy or girl, from the age of five to fifteen, how little attention is given to the growth and physical changes which necessarily occur at this most important period of life! The age of the child should be considered; the place of schooling, the hours of confinement and recreation, the number and kinds of studies, together with the modes of teaching, should all harmonize with physical laws—especially those of the brain.

The system or mode of treating, in education, all children as though their *organizations were precisely alike*, is based upon a false and unnatural theory. Great injury, in a variety of ways, results from this wrong treatment; in fact, injuries are thus inflicted upon the sensitive organizations and susceptible minds of young children, from which

[1] From "Medical Problems of the Day"—a Discourse before the Massachusetts Medical Society.

they never recover. That many of our most independent and clear-headed educators themselves express so much dissatisfaction with the working and results of our schools, affords evidence that something is wrong in the present system. As we contemplate the great improvements made in education for the last thirty or forty years, and are surprised that educators were content to tolerate the state of things then existing, so will the next generation, when still greater and more radical changes shall have been introduced, look back with astonishment at this generation, and wonder that it was so well satisfied with its own methods. When our educators become thoroughly convinced that physical development as a part of education is an absolute necessity—that a strict observance of the laws of physiology and hygiene is indispensable to the highest mental culture—then we shall have vital and radical changes in our educational system; then the brain will not be cultivated so much at the expense of the body, neither will the nervous temperament be so unduly developed in proportion to other parts of the system, now so often bringing on a train of neuralgic diseases which cannot easily be cured, and exposing the individual to the keenest and most intense suffering which all the advantages of mental culture fail, not unfrequently, to compensate.

The more this whole subject is investigated, the more reason we shall find for making allowances or some distinction in scholastic discipline with reference to the differences in organization of children, and for adapting the hours of confinement and recreation, the ventilation and temperature of school-rooms, the number and kinds of studies, the modes of teaching, etc., to the laws of the physical system. But another and still more important change must take place. Some time —may that time be not far distant!—there will be a correct and established system of *mental science*, based upon physiological laws; and, until this era arrives, the modes and methods of education must remain incomplete and unsatisfactory. The principles of this science, in the very nature of things, must rest upon a correct knowledge of the laws and functions of the brain; and, until these are correctly understood and reduced to a general system, all education must be more or less *partial*, *imperfect*, and *empirical*. While the old theories of metaphysicians are very generally discarded, they still have practically a powerful influence in directing and shaping our educational systems and institutions. In the selection and arrangement of studies very little attention is paid to the peculiar nature or operations of the various faculties of the mind, or the distinct laws that govern their development and uses. For illustration, instead of educing, drawing out and training, all the mental faculties in their natural order and in harmony, each in proportion to its nature or importance, the memory is almost the only faculty appealed to in every stage of education; and this is so crammed and so stuffed that frequently but little of the knowledge obtained can be used advantageously. Instead of developing the ob-

serving faculties by "object-teaching," appealing to the senses of sight and hearing, those two great avenues of knowledge, or giving much instruction *orally*, we require the scholar to spend most of his time in studying and poring over *books*, mere *books*. The mind is treated as a kind of general receptacle into which knowledge almost indiscriminately must be poured, yes, forced, without making that knowledge one's own, or creating that self-reliance which is indispensable to its proper use. In this way the brain does not work so naturally or healthily as it ought, and a vast amount of time, labor, and expense, is wasted—nay, worse than wasted. From this forced and unnatural process there often results not only a want of harmony and complete development of all parts of the brain, but an excessive development of the nervous temperament, and not unfrequently an irritability and morbidness which are hard to bear and difficult to overcome. And not unfrequently it ends in a permanent disease of the brain, or confinement in a lunatic asylum.

When we take a careful survey of the various discussions and diverse theories on this subject, considered metaphysically, and then compare them with the great improvements and discoveries in the physical sciences for the last fifty years bearing upon the same subject, the change or progress looks mainly in one direction, viz., that all true mental science must ultimately be based upon physiology. Here is a great work to be performed, and when accomplished it will constitute one of the greatest, most valuable, and most important achievements, that was ever wrought in the history of science. A vast amount of positive knowledge has already been accumulated on this subject, by various writers, but a great work, by way of analysis, observation, and induction, and of further discoveries as to the functions of the brain, remains to be completed. This work must be performed, in a great measure, by persons profoundly versed in the physical sciences; and no small proportion of it must come from the observations, labors, and contributions, of medical men.

THERMAL DEATH-POINT OF LIVING MATTER.[1]

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II.

ALTHOUGH it is doubtless true that the superior dryness of seeds does enable them to resist the influence of heat longer than moist eggs are able to do, and therefore also enables them apparently to resist for a brief period a temperature notably higher than would have proved fatal to them had they been in a moist state—it

[1] From author's advance sheets.

is altogether another question when we have to decide whether moist Bacteria or their germs are endowed with this seed-like property of developing after desiccation. To maintain his position, Spallanzani was compelled to assume that they did possess this potentiality. Modern science, however, on the basis of experiment, declares that they have no such property. We are told most unreservedly by Prof. Burdon-Sanderson,[1] not only that "the germinal particles of microzymes (Bacteria) are rendered inactive by thorough drying without the application of heat," that is, by mere exposure to air for two or three days at a temperature of 104° Fahr., but also that, "fully-formed Bacteria are deprived of their power of further development by thorough desiccation." Thus is the most important assumption made by Spallanzani swept away, and with it all the strength that his position may have appeared to possess. Neither he, nor any of his followers, can hope to save their germs from the full action of heat by assuming the preëxistence of a protective desiccation, when they are told, on the unquestionable authority of Prof. Sanderson, that such desiccation would be in itself destructive to them.

We are left, therefore, now face to face with only one other question. Has the progress of science, it may be asked, since the time of Spallanzani, in any way tended to strengthen the possibility that Bacteria-germs or any forms of living matter in the moist state can resist the destructive action of boiling water, even for two or three minutes? And to this question a negative answer may be unreservedly given, since the progress of science has shown, on the contrary, that such a supposition becomes more and more improbable in the light of all uncomplicated investigations bearing on the subject. To these results of modern research I must now call the reader's attention.

In the first place, the specific question with which we are more immediately concerned, as to the thermal death-point of Bacteria and their germs, has itself been answered by most decisive experiments. As the writer has elsewhere already shown,[2] all direct experimentation on this subject leads to the conclusion that Bacteria and their germs, whether visible or invisible, are killed by a brief exposure to a heat of 140° Fahr. in the moist state. Thus Dr. Sanderson's experiments having proved that the germs of these organisms are, as regards their ability to withstand desiccation, related to eggs rather than to seeds, the writer's own experiments tend to strengthen this resemblance by showing that these Bacteria-germs also (like the eggs with which Spallanzani experimented) are invariably killed at a temperature of about 140° Fahr.

Although, therefore, my experiments are not favorable to Spallanzani's assumptions, they are entirely in accordance with his experiments. The thermal death-point ascertained by him for the eggs of

[1] "Thirteenth Report of the Medical Officer of the Privy Council," p. 61.

[2] "Proceedings of Royal Society," 1873, No. 143, p. 224, and No. 145, p. 325.

Insects and of Batrachia, agrees almost exactly with that which I have established for Bacteria-germs, although at the time my own experiments were made I was unaware of these particular results obtained by Spallanzani.

Is there, then, any thing in this fact concerning Bacteria and their germs at all at variance with what we might have been led to expect from our knowledge about the capacity for resisting heat shown by other kinds of living matter? Here, again, a negative answer may be unreservedly given. The grounds for this opinion must, however, be set forth, and, in dealing with this important question, I will range what I have to say under the following heads: 1. The results obtained by many other investigators, working quite independently of one another, (and in many cases also without distinct reference to the Origin-of-Life question), all go to show that different kinds of living matter are killed when in the moist state at or below the temperature of 140° Fahr. 2. The only known exceptions to this rule are cases of a special kind differing altogether from those with which we are at present concerned. 3. Our knowledge concerning the thermal death-point of Living Organisms and of Living Matter is remarkably harmonious, and is in accordance therefore with what we know concerning the unity of living matter generally. 4. The assumptions entertained by some, in support of their notion that living matter unaccustomed to the influence of heat is able to resist the destructive action of boiling water, are of the most frivolous nature—alike unsupported by experiment and contradicted by all ordinary experience.

1. Liebig proved that sugar-yeast (*Torula cerevisiæ*) entirely lost its power of growth and germination at 140° Fahr. It has been ascertained by Tarnowski, after numerous experiments conducted, as Sachs says,[1] "with all possible precautions," that spores of Penicillium and other common fungi, also most closely related by nature to Bacteria, "entirely lost their power of germinating when heated in their own nourishing fluids" to a temperature of 131° Fahr. Again, it has been ascertained by Dr. Timothy Lewis[2] that the germs of tape-worms are invariably killed at the temperature of 131°, while Prof. Mantegazza has shown that the male reproductive particles of frogs are killed by exposure to the same heat. So far, therefore, concerning germs, in addition to what I have already mentioned about Spallanzani's observations upon the eggs of Insects and Batrachia. Turning now to adult organisms of different kinds or to their elemental parts, the following facts may be cited: Pouchet[3] found that all kinds of Ciliated Infusoria were certainly killed at 131° Fahr., and while confirming this observation the writer found that a brief exposure to this temperature

[1] "Lehrbuch der Botanik," third edition, p. 626.

[2] "Eighth Annual Report of the Sanitary Commissioners with the Government of India," 1871, p. 139.

[3] "Nouvelles Expériences," etc., 1864, p. 38.

always sufficed to kill Amœbæ, Monads, Euglenæ, Desmids, Rotifers, Nematoids, and other minute aquatic organisms. The writer did not try to ascertain what was the lowest temperature which would prove fatal to these organisms, though this has been done by other observers. Spallanzani, for instance, ascertained that Ciliated Infusoria, Water-fleas, Leeches, Nematoids, and other worm-like creatures, all perished at 107–113° Fahr.; while Max Schultze,[1] and Kühne,[2] in part working over the same ground, have quite recently fixed the limits for such organisms at temperatures varying between 104° and 113° Fahr. At these temperatures the protoplasm entering into the formation of such organisms as well as that of the tissue-elements of higher animals was not only killed, it became coagulated and assumed the condition named by Kühne "heat-rigidity." Both Max Schultze and Kühne also found that the protoplasm of plant-cells with which they experimented was always similarly killed and altered by a very brief exposure to a temperature of 118½° Fahr. as a maximum. All accurate new observations, therefore, go to prove that different kinds of living matter, whether in the form of germ or of developed organism, are killed by a brief exposure in the moist state to a temperature at or below 140° Fahr.

2. So far I have been referring to the influence of heat upon living matter when it is suddenly applied to an altogether unaccustomed extent. This is the mode of operation with which we are especially concerned, as, with the view to the interpretation of experiments on the Origin-of-Life question, we wish to know the effects of great heat upon organisms accustomed to ordinary atmospheric and aquatic temperatures. On the other hand, it should be pointed out that organisms have been found living in hot springs at temperatures very considerably above those I have just been quoting; although the very highest of the temperatures, under the influence of which living things have been reported as existing in thermal springs, is still a few degrees below the boiling-point of water. The various observations that have been made upon this subject have been collected and criticised with much care by Prof. Jeffries Wyman,[3] to whose paper I would refer the reader. The most remarkable instances of this kind, in which Confervæ, or allied organisms, have been met with—that is, the highest temperatures cited which are at all trustworthy—are thus summarized by Prof. Wyman: "The statements we have quoted," he says, "give satisfactory proof that different kinds of plants may live in water of various temperatures, as high as 168° Fahr., as observed by Dr. Hooker in Sorujkund; 174° as observed by Captain Strachey in Thibet; 185° as observed by Humboldt in La Trinchéra; 199° as observed by Dr.

[1] "Das Protoplasma," Leipsic, 1863, pp. 33, 46.

[2] "Untersuchung über das Protoplasma und die Contractilität," Leipsic, 1864, pp. 46, 103.

[3] *American Journal of Science and Arts*, vol. xliv., September, 1867.

Brewer in California; and 208° as observed by Descloizeaux in Iceland." As we have no grounds for criticising these observations, we are bound to look upon them, provisionally at least, as correct and taken with all due care, though it is only fair to add that both Max Schultze and Cohn appear to be not altogether satisfied with some statements of the same kind.[1] Such instances, if thoroughly accurate, may perhaps be taken as examples of the highest temperature which it is possible for living matter to endure, even where it has been inured to its influence in the most gradual manner. And the real point of view from which these facts should be regarded is, indeed, pointed out by Prof. Wyman when he says: "Having become adapted through a long series of years to their surroundings, such organisms may be supposed to live under circumstances the most favorable possible for sustaining life at a high temperature. It is a well-known physiological fact that living beings may be slowly transferred to new and widely different conditions without injury; but if the same change is suddenly made, they perish. In the experiments made in our laboratories, the change of conditions is relatively violent, and therefore liable to destroy life by its suddenness."

3. If we omit, therefore, the facts concerning the existence of living organisms in thermal springs which are altogether peculiar, and which lie outside the boundaries of our present inquiry, all that we know about the unaccustomed influence of high temperatures upon living things can easily be shown to be even more harmonious than it may at first glance appear. We have only to bear in mind two or three general principles in order to be able to harmonize the several experimental results arrived at with the now very generally admitted doctrine as to the oneness or generic resemblance existing between all forms of living matter. We must bear in mind, first of all, the consideration enforced by Spallanzani, that there are different grades of vitality, or, in other words, forms of living matter which exhibit more or less of the phenomena known as vital, and that of these forms those which exhibit the most active life are those which would be most easily killed by heat. Thus we should expect the latent "life" of the germ, egg, or seed, to be less easily extinguished than the more subtile, and, at the same time, more active life of the fully-developed tissue-element or organism; and we should also expect that the vegetal element or organism would, as a rule, be less readily killed than the more highly-vitalized animal element or organism. These principles, based upon the consideration of relative complexity of life, are, however, subject to the influence of a disturbing cause, since we must also take into account, in the case of animals, whether we have to do with the elements of a warm-blooded or a cold-blooded organism, owing to the fact that custom or habitual conditions tend to render the more active tissue-elements of warm-blooded animals better able to withstand the

[1] Max Schultze, "Das Protoplasma," Leipsic, 1863, p. 67.

influence of heat than similar elements of less highly vitalized cold-blooded animals. Keeping these considerations in view, therefore, we may see by the following figures how harmonious are the facts already ascertained:

TEMPERATURES AT WHICH DEATH OCCURS.

Simple aquatic organisms (*Spallanzani, Max Schultze, and Kühne.*)	are killed at	104°–113° Fahr.
Tissue-elements of cold-blooded animal—Frog (*Kühne.*)	"	" 104°
Tissue-elements of warm-blooded animal—Man (*Stricker and Kühne.*)	"	" 111°
Tissue-elements of Plants—Urtica, Tradescantia, and Vallisneria (*Max Schultze and Kühne.*)	"	" 116½°–118½°
Eggs, Fungus-spores, and Bacteria-germs (*Spallanzani, Liebig, Tarnowski, and others.*)	"	" 122°–140°

So far as we can ascertain by really scientific methods, free from all obvious possibilities of misinterpretation, these are the temperatures which undoubtedly kill the different varieties of that common life-stuff known as Protoplasm—the "physical basis of life," as it has been termed by Prof. Huxley. That it should present this comparative unity in its behavior toward heat as well as to other physical agencies, is surely not in antagonism with the most generally-approved biological doctrines, of which Prof. Huxley has made himself the most celebrated exponent in this country. In his own forcible language he tells us as follows: "Beast and fowl, reptile and fish, mollusk, worm, and polype, are all composed of structural units of the same character, namely, masses of protoplasm with a nucleus. . . . What has been said of the animal world is no less true of plants. . . . Protoplasm simple or nucleated is the formal basis of all life. . . . Thus it becomes clear that all living powers are cognate, and all living forms are fundamentally of one character."[1]

4. I now turn to say a very few words concerning the general attitude and specific statements made by those who, wishing not to give in their adherence to the fact of the occurrence of "spontaneous generation," affect to believe that Bacteria-germs or other kinds of living matter can resist the influence of boiling water.

In the first place, it should be said that not one of these persons has striven to justify his position by scientific evidence bearing directly upon the death-point of Bacteria and their germs, while several of them have glaringly attempted to make good their position in the most unscientific manner, that is, by adducing experiments admitting of two interpretations as though they were instances only admitting of one, and then of these two possible interpretations selecting that

[1] "Lay Sermons," pp. 126–129.

which the experiments were not originally destined to illustrate, and which is, moreover, contradicted by other less equivocal evidence, as to the very existence of which those who adopt this course take care to say nothing. This is a kind of treason to Science of which I hope the future may prove less prolific than the past has been.

And, if we turn now to the specific statements made by those who profess to believe that Bacteria and their germs are able to resist the influence of boiling water, we discover in the first place that all who advance such suppositions find it convenient to pass unnoticed the several series of experiments by which it has been proved that Bacteria and their germs are uniformly killed by an exposure to 140° Fahr. for five minutes. My opponents find it most convenient to take no notice of these experiments, though no one has as yet attempted to dispute their cogency. They prefer to talk vaguely, as though these experiments had never been made, and to adduce various theoretical reasons whose validity they do not attempt to test experimentally. To do this, indeed, would be a vain attempt, because they must be aware that such suppositions as they advance are opposed to generally-accredited scientific doctrines, even if they have not already been specifically refuted.

The suppositions principally dwelt upon may be ranged under three categories:

(*a.*) It is assumed by some that the mere minuteness of the germs of Bacteria may serve to protect them from that destructive influence which heat exercises upon living matter generally.[1] This is an old objection entirely unsupported by facts, and those who dwell upon it may be reminded that it was unhesitatingly rejected by the former chief of their school, Spallanzani, who said, "Un raisonnement de cette sorte est absolument contraire à toutes les notions que nous avons du feu." They may be further reminded that the writer's own experiments absolutely meet this objection, since they refer to the death-point of invisible germs of Bacteria just as much as to the death-point of those which are visible.[2]

(*b.*) Others, without definitely committing themselves to the belief that Bacteria-germs can resist the destructive influence of boiling water when they are immersed in it, affect to believe that some germs may have escaped its influence by being "spurted" out of the fluid on to the sides of the glass when the process of boiling commenced. How any such germs could escape the moistening and destructive influence of the hot steam with which they would still be in contact

[1] Some of those who rely upon this supposed reason have resorted to direct attempts to ascertain the death-point of the germs of other organisms, although their results have been, in part, vitiated by the evaporation of the drop of fluid employed, so that the organisms were subsequently exposed to the higher degrees of heat in a *dry* state.

[2] *See* "Proceedings of Royal Society," 1873, No. 143, p. 227.

these reasoners do not say, though some of them are cautious about openly suggesting an antecedent and protective state of extreme desiccation in the face of Dr. Sanderson's experiments proving that this would be in itself destructive. The futility of this reasoning has, however, been completely demonstrated by the fact that organisms will occur just as freely under conditions where no such objection can be alleged, that is, when the vessel and its contents are heated by submergence in boiling water, after it has been hermetically sealed—a mode of heating that has been occasionally adopted by different experimenters since the time of Spallanzani.

(*c.*) The third objection raised is no less remarkable, owing to its being similarly brought forward as an unsupported supposition in the face of much other evidence testifying to its nullity. When the writer's earlier experiments were first recorded, the public was authoritatively told by Prof. Huxley that the results were unworthy of credence, because the fact that tons of meats and vegetables were annually preserved from putrefaction by a very similar process was in itself the strongest evidence that he had in some manner deceived himself. It was never suggested or thought of, therefore, at this time, that such moist meats and vegetables were incapable of being heated through, even when pounds of them were aggregated together. It was, in fact, implicitly said that they could be so heated, and the fact of the preservation of the meats and vegetables was itself deemed to be the best evidence that all germs contained in their interior had been killed. Now that the writer has demonstrated to unbelievers, and when others have ascertained for themselves, that organisms are to be met with and that putrefaction will occur within almost airless and hermetically-sealed flasks whose contents have been previously boiled, the tactics of these unbelievers are entirely changed. Forgetting altogether their previous objection upon which they relied so long as they doubted the writer's facts, they now advance the interpretation of his results, which must carry with it its own stultification to the minds of those who have not entirely forgotten their previous position. The writer's methods are declared to be faulty for not freeing his infusions from all particles, however minute and however soft. The oracles now shake their heads, and talk with apparent learning about "the protective influence of lumps." While heat was previously supposed to be capable of operating as a germ-killer through pots of meats and vegetables, and while it has been proved to act in the same way through the thick and dry envelopes of seeds, now a pea or a minute particle of cheese, even though smaller than a pin's head, is thought to exercise a "protective influence" over imaginary germs! Such puerilities may safely be left to die a natural death, though it may be as well to remind those who trust to them, that, although they do not put their notions to the test of direct experiment, others have, for certain practical reasons, had occasion to do so. Dr.

Timothy Lewis, who has been for some time in Calcutta, carrying on, in concert with Dr. D. Cunningham, important sanitary investigations, has, among other things, directed his attention to the vitality of tape-worm germs in cooked meat. He proved, first, that tape-worm germs are undoubtedly killed by exposure for five minutes to a temperature of 135°–140° Fahr.; and then, with a view of ascertaining also how far they would be likely to experience such a temperature in the ordinary process of meat-cooking, he made other important observations having considerable interest for us. Dr. Lewis found that when legs of mutton had been put into the boiler almost as soon as the water, their central temperature averaged 140° Fahr. by the time the water around them had reached the boiling-point, and that, after the water had boiled for five minutes, the internal temperature of the legs of mutton which had remained in the boiler had on an average reached 170°. This is a practical method of dealing with the question which those skeptical dreamers who talk of the "protective influence of lumps" would do well to imitate.

After this I may perhaps be deemed fully justified in quoting two very typical experiments for the consideration of those who stave off their belief in the occurrence of "spontaneous generation" either by relying upon insufficient reasons for doubting the influence of boiling water, or because of their following Pasteur, Cohn, and others, in supposing that certain peculiar Bacteria-germs are not killed except by a brief exposure to a heat of 227° or 230° Fahr. For, even if we could grant them these limits, of what avail would the concession be toward staving off the dreaded admission of the occurrence of "spontaneous generation," in the face of such experiments as those which follow?

Experiment I.—A strong infusion of turnip was rendered faintly alkaline by liquor potassæ, and to this a few separate muscular fibres of a codfish were added. Some of this mixture was introduced into a flask of nearly two ounces' capacity. Its neck was drawn out and afterward hermetically sealed by the blow-pipe flame, while the fluid within was boiling. When thus closed the flask was about half full of fluid. It was then introduced into a digester which was gradually heated, and afterward kept at a temperature of 270–275° Fahr., for twenty minutes, though it seems also well to point out that, if we include the time taken for the water of the digester (in which the closed flask was immersed) to attain this heat, and also again to cool down to 230° Fahr., this flask was exposed to temperatures above 230° Fahr. for one hour, as I myself carefully noted at the time. When withdrawn from the digester the closed flask was kept at a temperature of 70–80° Fahr. for eight weeks, and during part of this time it was exposed to the influence of direct sunlight. After it had been ascertained that the flask was free from all crack or fault, its neck was broken, in order that its contents might be examined. The reaction of the fluid was found to have become decidedly *acid*, and it had a sour though not

fetid odor, as though a fermentative process had been taking place in the solution. The fluid was very slightly turbid, and there was a well-marked sediment consisting of reddish-brown fragments, and of a light flocculent deposit. On microscopical examination the fragments were found to be portions of altered muscular fibre, while the flocculent deposit was composed for the most part of granular aggregations of *Bacteria*. In the portions of fluid and of deposit which were examined, there were thousands of *Bacteria* of most diverse shapes and sizes, either separate or aggregated into flakes. There were also a large number of monilated chains, of various lengths, of a kind very frequently met with in abscesses and other situations, where pyæmia or low typhoid states of the system exist, in the human subject. There were, in addition, a large number of *Torula* corpuscles, as well as of brownish, nucleated, spore-like bodies, gradually increasing in size from mere specks, about $\frac{1}{30000}$th up to $\frac{1}{2500}$th of an inch in diameter. Lastly, there was a small quantity of a mycelial *Fungus* filament, bearing short lateral branches, most of which were capped by a single spore-like body.

EXPERIMENT II.—A strong infusion of common cress (*Lepidium sativum*), to which a few of the leaves and stalks of the plant were added, was inclosed in an hermetically-sealed flask in the same way, heated in the digester at the same time (and therefore to the same temperature), and was subsequently exposed to the influence of the same conditions as I have already mentioned in connection with the last experiment. This flask was, however, opened one week later—that is, at the close of the ninth week after it had been heated in the digester to 270–275° Fahr. Before breaking the neck of the flask, the inbending of the glass under the blow-pipe flame showed that it was still hermetically sealed. The reaction of the fluid was found to be distinctly acid, though there was no notable odor. The fluid itself was tolerably clear and free from scum, but there was a dirty-looking flocculent sediment at the bottom of the flask, among the *débris* of the cress. On microscopical examination (with a $\frac{1}{12}$th "immersion" objective) much altered chlorophyll existed, either dispersed or aggregated among the other granular matter of the sediment, and among some of this three minute and delicate *Protamœbæ* were seen, varying in form, and creeping with moderately rapid, slug-like movements. They contained no nucleus, and presented only a few granules in their interior. In the same drop of fluid, and also in others subsequently examined, more than a dozen very active *Monads* ($\frac{1}{4000}$th of an inch in diameter) were seen, each provided with a long, rapidly-moving lash by which neighboring granules were freely knocked about. There were many smaller motionless and tailless spherules of different sizes, whose body substance presented a similar appearance to that of the *Monads*—and of which they were, in all probability, earlier developmental forms. There were also several unjointed *Bac-*

teria, presenting most rapid progressive movements accompanied by quick axial rotations. Many *Torula* corpuscles and other *Fungus* "spores" also existed, as well as portions of a mycelial filament containing equal segments of colorless protoplasm within its thin investing membrane.

A drop of the fluid containing several of these active *Monads* was placed for about five minutes on a glass slip in a warm-water oven maintained at a temperature 140° Fahr. All the movements of the *Monads* ceased from this time, and they never afterward showed any signs of life.

These experiments are two of the most remarkable selected from several others in which even higher temperatures were originally had recourse to in order to free the fluids and flasks generally from any thing like a trace of living matter. Nothing, that has yet been alleged by way of objection to the admission of "spontaneous generation" as an every-day fact, at all affects such experiments as these. The shortest way out of the difficulty would therefore be to doubt the facts. I can assure the reader, however, that they are as true and just as reliable as those other results obtained when working with lower temperatures, which, though strongly disbelieved in at first, are now generally recognized as trustworthy. And, although these now accredited results abundantly suffice, in face of our present knowledge concerning the limits of vital resistance to heat, to establish the strongest probability of the occurrence of "spontaneous generation," yet such experiments as those which I have now recorded even still further confirm this view, since it becomes incredible that, while all known forms of living matter with which accurate experiment has been made inevitably perish at or about 140° Fahr., the particular examples of the same forms which appear within our sealed flasks have been able to survive a much longer exposure to 270°–275° Fahr. If this were true, then indeed would the cultivation of Science be a vain pursuit—"uniformity," in fact, must be postulated and granted, or Science with humbled and sorrowful crest must retire from the field.

A word or two must be said in conclusion with reference to the interpretation which should be attached to such experiments as those just recorded. And this subject cannot be better introduced than by means of the following extract from the already-quoted and valuable paper by Prof. Jeffries Wyman. He says: "There can therefore be no certainty of the existence of spontaneous generation in a given solution, until it can be shown that this has been freed of all living organisms which it contained at the beginning of the experiment, and kept free of all such from without during the progress of it. On the other hand, this kind of generation becomes probable, whenever it is made certain that Infusoria are generated in solutions in which the conditions just mentioned have been complied with. We say prob-

able, because their appearance under such circumstances would not amount to a proof. The absolute proof of spontaneous generation must come from the formation of living organisms out of *inorganic* matter. If Infusoria are generated in solutions of organic matter, independently of spores or germs, the question may be fairly raised whether we do not begin the experiment with materials in which life already exists, even though this material is not in the form of distinct organisms." Now, these last few lines, as they at present stand, tend to convey to the reader very erroneous impressions, and yet I am aware that views of the same kind are very commonly expressed, and seem to exist in an inchoate or half-realized form in the minds of many distinguished persons. It is for this reason, and on account of the authority attaching to Prof. Wyman's statements, that I am induced to take notice of this particular passage in order to attempt its rectification.

In the first place, then, under the old term, "spontaneous generation," are included two processes quite distinct from one another—namely, Heterogenesis and Archebiosis. With regard to Heterogenesis, this is merely the opposite of Homogenesis: and the latter is the name for that mode of generation or reproduction among living things which is looked upon with most respect and which is most generally known. It is the process by which "like produces like," that is, where the offspring grow into beings like their parents. In Heterogenesis, on the other hand, we have the birth of dissimilar products, the beginning of a new branch from a "life-tree," in which the offspring have no tendency to assume the parental type. This occurs, for instance, where the protoplasmic matter of an animal or of a vegetal cell becomes modified and resolved into Bacteria. Here we have to do with the mere transformation of living matter. It can, therefore, only take place where living matter preëxists. And seeing that many, among whom I may especially mention Needham,[1] Pouchet, and Trécul, have, both now and formerly, understood by the phrase spontaneous generation merely such a process of metamorphoses of living matter as is implied by the term Heterogenesis, it is very misleading to say that "the absolute proof of spontaneous generation must come from the formation of living organisms out of inorganic matter."

It seems obvious, however, that, when Prof. Wyman wrote this passage, he, forgetting the more common acceptation of the phrase "spontaneous generation," must have used it in the same sense as I now employ the term Archebiosis—in the sense, that is, of life-origination. But, even taking it in this sense, how far, we may ask, is Prof. Wyman justified in saying that its proof "must come from the formation of living organisms out of inorganic matter?"

The statement is, in my opinion, one which cannot be logically entertained by a believer in the ordinary physical doctrines of life, and

[1] *See* "The Beginnings of Life," vol. i., pp. 246–252, and vol. ii., p. 181.

consequently should be professed by no consistent believer in Evolution. Those who do not assent to these doctrines would probably never be able to believe in Archebiosis at all—to the "vitalist" life is an immaterial principle specially created, and therefore our flask experiments terminating in the birth of new organisms, if they carried with them any convictions at all, would simply be regarded by him as proving the occurrence of Heterogenesis. This is the view to which a vitalist would be driven, if he had become convinced that no germs of Bacteria, or of such organisms as are found in our flasks, could have survived the preliminary process of heating. Such a vague sort of position is not open, however, to those who believe in the now generally-accepted physical doctrines of life. They are bound to recognize the undoubted distinction which exists between mere dead organic matter and that organic matter which displays the phenomena of life. They should no more think of calling a body "living" which could not be made to display the characteristics of life, than they would call a body "magnetic" when it would show none of the properties pertaining to magnetism. If they had learned, therefore, that living matter when exposed to heat of a certain intensity became lifeless matter, the process by which new living protoplasm comes into existence among this dead organic material would be, for them, as much an instance of its new independent origin as if the process had occurred in the midst of mere inorganic elements. The term Archebiosis is therefore applicable to the process that must take place in our ordinary flask experiments where we have to do with dead organic matter, just as it is also applicable to those more primordial combinations which first gave birth to living protoplasm. The continued occurrence of an independent elemental "origin" of living matter we are called upon to believe in at the present day, though the actual steps of the process by which it takes place are unfortunately as completely unknown to us as are the steps by which its "growth" occurs whether from organic or from inorganic materials.—*Contemporary Review.*

ADDRESS BEFORE THE AMERICAN ASSOCIATION.[1]

By Prof. JOSEPH LOVERING.

I.

Instruments in Physical Progress.

WHEN the States-General of France were assembled for the last time at Versailles, after a long interval of inactivity, and an inaugural address was pronounced by the Bishop of Nancy, Mirabeau

[1] Retiring Address before the American Association for the Advancement of Science, at the Hartford meeting, August 14, 1874, by the ex-president.

passed upon his performance the sweeping criticism that he had missed the grandest opportunity ever offered to man for saying something or holding his tongue. And, whenever this Association, comprising not only those who teach, but many who create science, assembles, as it now does, to listen to the address of its retiring president, if he is duly sensible of his responsibility, he would gladly avail himself of Mirabeau's alternative, either of being equal to the occasion or of being silent. But the rule of the Association, adopted in the original draft of the constitution at Philadelphia, and the example of my predecessors which I am unwilling to reverse, leave me no choice; and when I see around me, not the terrible monsters of the French Revolution, maddened by the miseries of a down-trodden country, but calm and high-minded lovers of truth, I feel sure of a just and generous criticism. Welcome, then, the precious opportunity, enjoyed by the president of this Association, of discussing some of the great themes of science before an audience which has for its nucleus the original investigators, discoverers, and inventors in the country, and which, like the sun, is surrounded by an extensive chromosphere only a little less brilliant than the central body by contrast; and let my earnest endeavor be not to abuse or waste the great privilege.

I am confronted on the very threshold of my address by the doubt whether it were better to beat out the little bit of golden thought, for which I have time and capacity, into a thin leaf which shall merely gild the whole vast surface of scientific investigation, even for a single year, or to condense it into a solid though minute globule, only big enough and bright enough to light up some narrow specialty. The general practice which prevails, of selecting a president alternately from the two principal sections into which the Association is divided, will justify me in paying my particular addresses to the physical sciences, knowing that the large and active department of Natural History will be properly treated in its turn by those most competent to do it. Not even the capacious mind of a Goethe, a Humboldt, a Whewell, or a Herbert Spencer, is large enough to give a decent shelter to all the subjects which come within the scope of this Association. At the same time I must say that I sympathize with the remarks made by President Hunt at Indianapolis, when he questioned the propriety of excluding geology from the ranks of the physical sciences; only I would give them a still wider significance. Physical science is distinguished from natural history not so much by its subjects as its methods. In my imagination, I can picture to myself all these subjects as being handled in the same masterly grasp of mechanics and mathematics by which the physical astronomer holds in his hands the history and the destiny of the solar system. What is only a dream or a fancy now may become a reality to the science of the future. Why, asked Cuvier, may not natural history some day have its Newton, to whom the laws of circulation of the sap and the blood will be only as

the laws of Kepler? With such an indorser, I may venture to quote these words of a consummate mathematician without fear of their being cast aside by the naturalists as one of Bacon's Idols of the Tribe: "An intelligence which at any given instant should know all the forces by which Nature is urged, and the respective situations of the beings of which Nature is composed, if, moreover, it were sufficiently comprehensive to subject these data to calculation, would include in the same formula the movements of the largest bodies of the universe and those of the slightest atom. Nothing would be uncertain to such an intelligence, and the future, no less than the past, would be present to its eyes." The time has already come when a knowledge of physical laws and familiarity with the instruments of physical research are indispensable to the naturalist. I would not recommend that dissipation of intellectual energy which will make a man superficial in all the sciences but profound in none. But Helmholtz has established, by his own example, the possibility of being an eminent physiologist, and, at the same time, standing in the front rank of physicists and mathematicians. The restlessness of human inquiry will never be satisfied with knowing what things are, until it has also discovered how and why they are, and all the relations of space, time, matter, and force, in all the kingdoms of Nature, have been worked out with mathematical precision.

It is a happy circumstance in the history of science, that this vast mechanical problem did not rush upon the mind at once in all its crushing generality. The solar system, with a despotic sun at the centre, competent to overrule all insubordination among planets and comets, and check all eccentricities and jealousies, and so far isolated from neighboring systems as to fear nothing from foreign interferences and entangling alliances, presented a comparatively simple problem; and yet the skill and labor of many generations of mathematicians have not yet closed up the argument upon this first case. On the orbits of this domestic system they have been sharpening their tools for higher and more delicate work. The motions of binary stars have also been brought under dynamical laws, and partially subjected to the rule of gravitation, so far as the astronomer can judge from the best observations which he can make upon those remote objects. But when he launches out, with his instruments and his formulas, into clusters of stars, even those of greatest symmetry, he is wholly at sea, without chart or compass or light-house, and with no other illumination than that which comes from a prophetic demonstration in Newton's "Principia." The mathematician has here to treat, not with an unlimited monarchy, as in the solar system, but with a republic of equal stars, and the dynamical condition of the clusters is involved in all the obscurity of molecular mechanics; for it matters not whether the individual members of a system are atoms or worlds, if the intervening spaces have corresponding magnitudes. Even in astronomy, the in-

spiration of mechanics and the pride of mathematics, how trifling is the region which has been subjugated to the rigid rules of the exact sciences when compared with the immense territories which remain under the jurisdiction of natural history, and must be studied, if at all, by the methods of the naturalist, though with an inverted microscope!

If, now, we circumscribe our outlook by the line which marks where physical science ends and natural history begins, it will be possible to examine only a few of the salient points in the prospect before us; and what these are will depend upon the point of view which we select. Whewell presents the history of any science at each of its successive epochs as circulating around one powerful mind, which figures as the hero of the drama, and whatever immediately precedes or follows is only the prelude or the closing strain to the great movement. In the philosophy of Comte, every science passes through a theological and metaphysical crisis before it reaches the healthy condition of positive knowledge, and its whole history is written out by him in these three acts. With Buckle, the progress of science, without which there could be no history, is coincident with the advance in civilization; but the action begins with science, and the reaction only comes from external causes. All that science and civilization demand is perfect freedom of thought. The worst enemy of both is the protective spirit in church and state, the former telling men what they must believe, the latter what they must do.

Each of these views of scientific development may be true, but not to the exclusion of all others. Metaphysical blindness or theological prejudice may block the way of science or defame its fair name. It has been stated that six members of the ultra-clerical party at Versailles voted against the appropriation for securing observations of the approaching transit of Venus, because they did not believe in the Copernican system, and this, too, while the echoes of the celebration of the four-hundredth birthday of Copernicus are still resounding over the earth! So, also, circumstances, and even accidents, may shape the course of discovery; the happiest of all accidents, however, being the appearance on the stage of the discoverer himself.

The point of view which I have chosen for reviewing the close and advancing columns of the physical sciences is this: Are there any improvements in the weapons of attack, or have any additions been made to them? These are of two kinds: 1. Instruments for experiment, and 2. The logic of mathematics. These are the lighter and the heavier artillery in this peaceful service.

If we cast a hurried glance over that long period of experimental research which began with Galileo and ended with Davy, we recognize, as the chief instrumentalities by which physical science has been promoted, the telescope, the microscope, the pendulum, the balance, and the voltaic battery. It is not necessary for me to enlarge upon

the strength and accuracy which the battery and the balance have given to chemistry, or on the stretch and precision of vision which the telescope and microscope have bestowed on astronomy and physics. These instruments, the veterans of many a hard-fought battle, science still enjoys; not superannuated by their long service, but continually growing in power and usefulness. The little opera-glass with which Galileo first lifted the veil from the skies and awoke the thunders of the Vatican, has blossomed out into the magnificent refractors of Cambridge, Chicago, and Washington. The little reflector with which Newton, by a happy mistake, expected to supplant the lens, has grown into the colossal telescopes of Herschel, Rosse, and the Melbourne Observatory. The spasmodic, momentary action of Davy's batteries, sufficient, however, to inaugurate a new era in chemistry, has been superseded by constant currents, which grumble not at ten hours a day. After lighting up the forelands of a continent during the night, they are fresh to work an ocean-telegraph the next morning. With all my wonder at this mysterious instrument, which serves so faithfully the cause of science and civilization, with renewed admiration of the microscope and the telescope, one of which transforms an invisible speck of matter into a universe, and the other collects the immensity of the heavens into a little celestial globe upon the retina of the eye, I must pause for a moment to eulogize that simplest and most modest of scientific tools, the pendulum.

With the eye of science Galileo saw in the leaning Campanile at Pisa, not a freak of architecture, but the opportunity of experimenting on the laws of falling bodies; and, in the adjacent cathedral where others admired the marble pavement or the vaulted roof, the columns, statues, and paintings, his attention was caught by the isochronous vibrations of the chandelier, which during the long centuries has never been absolutely at rest. When it is said that the pendulum has no rival as a standard of length except the metre, that it furnishes an exact measure of time, and that time is an indispensable element in the study of all motion, and also the most available means of obtaining longitude on the earth and right ascension in the heavens, a strong case has been made out for the practical and scientific usefulness of Galileo's discovery. During the long years of doubt in regard to the true figure of the earth, the pendulum maintained the cause of Newton in opposition to the erroneous reports of the geodesists, until Maupertuis, by a new measurement, flattened, as has been pithily said, the earth and the Cassinis at the same time. The shape, rotation, and density of the earth; the diminution of terrestrial gravity with an increase of distance from the centre; the local attractions of mountains, and secrets hidden below the surface of the planet, have been discovered or verified by the declarations of the pendulum, which, whether in motion or at rest, has never tired of serving science. And, in a wider sense, the pendulum has done for the electric and magnetic

forces what, in its restricted meaning, it did for gravity. That which Borda failed of accomplishing in the measurement of arcs, the pendulum realizes in its measurement of time: it multiplies its observations, eliminates its own errors, strikes its own average, and presents to science the perfect result. In 1851 a crowd of spectators were assembled in the Pantheon of Paris to witness the first performance by the pendulum of the new part prepared for it by Foucault, in which, obedient to its own inertia, and indifferent to the earth's rotation, it preserves the parallelism of its motion—an experiment startling, though not wholly unanticipated, and which has made a circuit of the earth. The new contrivance of Zöllner promises to indicate changes in the direction of a force as accurately as the common pendulum measures intensity.

Let us now consider what the physicists of our own day, and their immediate predecessors, have added to their rich inheritance of instrumental means, remembering all the time that, however impressive from their novelty these additions may be, and however manifold their applications, they have only supplemented the experimental methods which have been described without supplanting them. For the most part, the later devices would be useless without the coöperation of the earlier ones.

An interesting event in the history of science, which must be known to many of you, has taken place during the current year. In 1824, Poggendorff began to edit the *Annalen der Chemie und der Physik.* Under his supervision 150 volumes have been issued, containing 8,850 distinct communications from 2,167 different authors, the 193 papers of H. Rose outnumbering those of any other contributor. The history of physical and chemical discovery during the last fifty years might be written out of the materials treasured up in this single journal. In recognition of the signal service which Poggendorff has hereby rendered to science, his friends assumed the editorship of one volume in 1874, which is called the Jubilee volume (Jubelband).

In 1826, Poggendorff described, in Volume VII. of his journal, a device of his own invention for observing with exceeding nicety the movements of a magnetized bar. A mirror was attached to the bar and moved with it. From this mirror a beam of light was reflected into a theodolite. This was the origin of the happy thought of amplifying a trifling motion by making the finger of a long and delicate ray of light serve as a weightless pointer. A few years later, this idea was embodied by the mathematician, Gauss, in an instrument which he called the magnetometer. Since that time it has been continually budding out in new applications, scientific and practical. I need only recall to your recollection the beautiful method of Lissajous for compounding the vibrations of tuning-forks, and tracing in golden lines the curves which are characteristic of different musical intervals and varied phases of vibration. A new chapter has been opened in

mechanics for describing and explaining these strange and nameless curves; and, in acoustics, the ear has been dispossessed by the eye of what would seem to be its own by right divine, and it is no longer the best scientific judge of sounds. By new devices Koenig has translated time into space, and made visible the individual vibrations of the invisible air; and, in numerous ways, the mechanism of sound is as real to the eye as the sensation is to the ear.

With a bare allusion to the fact that every message which passes over the cable-telegraph is a tribute of indebtedness to the simple but comprehensive method of Poggendorff, I pass to two other cases of great difficulty and wide significance in which the same method has triumphed. I refer to the determination of the velocity of electricity and the velocity of light.

When Wheatstone devised and executed the ingenious experiment of producing three electrical sparks, not strictly at the same instant, but after the brief interval required by electricity to travel over one-quarter of a mile of copper wire, and then observing, not the sparks themselves, but their images, as seen in a mirror revolving with the prodigious volocity of 800 turns in a single second, and from the prolongation and relative displacement of these images deducing the velocity of electricity, the duration of the electrical light, and the duality in the direction of the transmitted disturbance, he delighted the brotherhood of science by the skill and boldness of his attempt, and astonished it by the extravagance of his results. For twenty years no one ventured to repeat the difficult experiment. When it was finally tried by Feddersen, and more recently by our own associate, Rood, the values which they assigned to the duration of the electrical light, and which could not be challenged, made still the wonder grow. So far as this mode of experimenting concerns the velocity of electricity, Wheatstone stands alone, and his estimate of this velocity (the largest known velocity in the universe unless we count in the velocity of gravitation) has never been brought to a second trial. Indirectly, it has been tested by some of the operations conducted upon land and ocean lines of telegraph. When the local times of two places are compared by means of electro-magnetic signals, sent alternately in opposite directions, the difference of longitude and the transmission-time of electricity can be disentangled from one another, by the strategy of mathematics, and the most probable value computed for each. The velocity which has been calculated from these longitude-campaigns falls far below that credited to Wheatstone. The apparent discrepancy is explained by a misinterpretation of Wheatstone's experiment. An experiment which proves that electricity runs through one-quarter of a mile of wire *at the rate* of 288,000 miles a second, does not justify the inference that it would move over 288,000 miles in one second. Anomalous as the case may be, electricity has no velocity in the ordinary sense. The transmission-time of the electrical disturbance is propor-

tioned to the square of the distance to be traveled. Therefore, the velocity has no constant fixed value, but varies with the length of the journey. This law, which is deduced from the mathematical theory of Ohm, introduces order among the experiments, where, otherwise, there would be chaos. It is not surprising that Wheatstone and the readers whom he addressed were misled by the original facts. Few men who have rendered signal services to science, and who have finally reached the highest pinnacle of fame, have suffered more from poverty and neglect, and waited longer for a recognition of their merits, than the modest student of Nuremberg. The slender volume which will perpetuate his name was indeed published at Berlin in 1827, and antedates Wheatstone's experiments by seven years. But the book was treated with contempt by a minister of state, to whom Ohm presented a copy, at his University of Cologne, and was first brought to the notice of English readers in 1841, when an English translation of it was effected through the agency of the British Association, and the Copley medal was presented to Ohm by the Royal Society of London. As late as 1860, when the same work was rendered into French, the translator admits that the mathematical theory of Ohm on the galvanic circuit, the elements of which have since rapidly circulated in popular text-books, was almost unknown in France, that high seat of science. If the serene but steady light of mathematics had not been dimmed by the blaze of experimental successes, and the teachings of Ohm had been heeded sooner, the science of electricity would have been the gainer, and the men of science would have been saved the mortification of treating the electro-magnetic telegraph as an impracticability.

When Wheatstone was a candidate to fill a vacancy in the corresponding members of the French Institute, it was objected that he had only made a brilliant experiment, but had not discovered a new principle. Arago came to his rescue, and asserted that he had introduced a powerful and fertile method of experimentation which would be felt in other sciences besides electricity. The French physicist lost no time in devising means for making good these claims. If it could be proved experimentally that the velocity of light was greater in air than in water, a capital fact in the contending theories of light would be settled forever. Arago planned the experiment and pressed its feasibility upon the Academy of Sciences with all the power and eloquence of his nature. At last he roused two younger physicists to undertake what his growing infirmities prevented him from doing with his own hands. The result declared in favor of undulations, and a fatal blow was dealt to the corpuscular theory of light which had vexed science since the days of Newton. If Fizeau and Foucault drew their inspiration from Arago, they owed their success to nothing except their own skill in devising and executing. Having tried the temper of their steel on this easier problem, they were ready for the grand attack, which was, to measure the absolute velocity of light.

The instrumental arrangements of these two experimentalists agreed only in the part which each borrowed from Poggendorff; the details differed so widely as to give to whatever agreement might appear in their results the force of an irresistible argument for their accuracy. The velocity of light, as found by Fizeau in 1849 by the artificial eclipses which the teeth of his revolving wheel produced, exceeds by about six per cent. the velocity which Foucault obtained, in 1862, with the moving mirror. The arithmetical mean of the two values comes very close to the astronomer's estimate of the velocity of light. But this simple average is precluded unless it can be proved that the two experiments are entitled to equal weight. The internal evidence, expressed by what mathematicians call the probable error, manifested a decisive preference for Foucault's result, and it has met with general acceptance. The soundness of the scientific judgment in this case has been placed beyond all cavil by Cornu, who has recently repeated Fizeau's experiment, with additional precautions, and resolved the discord into a marvelous accord. Fizeau's experiment, in spite of the numerical defect, was hailed as one of the grandest triumphs of experimental skill. In 1856 he received the prize of 30,000 francs which the Emperor of France had founded, to be given for the work or the discovery which, in the opinion of the five academies of the Institute, has conferred the greatest honor and service upon the nation. Hitherto, it had been supposed that nothing short of an interstellar or an interplanetary space was a match for the enormous velocity of light. And yet one physicist, by using a distance of less than six miles, and another, without going outside of his laboratory, have discovered what astronomers had searched heaven and earth to find out.

By these capital experiments the science of optics has achieved its own independence. Let us see what they have done, at the same time, for astronomy. The sequences in the eclipses of Jupiter's moons are modified by the velocity of light. The aberration of starlight is a measure of the ratio between the velocity of light and the velocity of the earth. For nearly two centuries our knowledge of the velocity of light leaned upon one or the other of these relations. If the velocity of light can be known from experiment, the problem may be reversed and the distance of the sun given to the astronomer. As soon as it appeared that Foucault's estimate of the velocity of light fell short of the astronomical valuation by about three per cent., it was certain that either the experiment was in error, or the received aberration was too small, or the reputed distance of the sun was too large. An error of three per cent. in the experiment or in the aberration was inadmissible. But it was conceivable that the distance of the sun should be at fault, even to this extent. The popular announcement that Foucault had picked a flaw in the astronomer's work was not correct. Astronomers had always known what those who pinned

their scientific faith on text-books did not expect—that the problem of finding the sun's distance was an exceedingly delicate case, and that an ominous cloud of uncertainty hung over their wisest conclusions. Whenever it is possible to interrogate Nature in more ways than one, Science is not satisfied with a single answer, nor with all the answers unless they agree. The transit of Venus, the parallax of Mars, and the tables of the moon, each can tell the sun's distance. But their testimony was contradictory, and neither one at all times repeated the same story. The question was, which to believe. Since 1824, when Encke published his exhaustive computations on the last transits of Venus, the distance which they assigned to the sun has been acquiesced in as the most probable. But the moon, as has been said, has always been a thorn in the sides of mathematicians. While practical and theoretical astronomers have been reducing its motions to stricter discipline, the suspicion has been steadily gaining strength in their minds that the distance adopted from the transits was too large. The effect of Foucault's experiment was, to intensify the doubt. The case of the twin transits of the last century, thought to have been closed forever by Encke, has recently been opened again by the astronomer Stone. When Venus has nearly entered upon the sun, the moment of interior contact is preluded by the formation of a slender ligature (called the black drop) between the nearest parts of the two disks—caused, perhaps, by irradiation. One observer has recorded the time when this ligature began, another the time when it was broken. In working up the observations of the last transits, both classes were not combined indiscriminately. Mr. Stone has re-examined the documents, classified differently the materials, and extracted from them two new and independent values for the sun's parallax. The reconciliation which he has suddenly brought about between the experiments of Cornu and Foucault, the motions of the moon, and the transits of Venus, is as perfect as it is surprising. Nevertheless, the approaching transits of Venus, the earliest of which is close upon us, will be welcomed, if not as the only possible way of solving a hard problem, at least for the confirmation which is demanded by a solution already reached; for able astronomers have dissented from the interpretation put upon the records by Stone. The minds of observers have been prepared for what their eyes are to see, in December, 1874, by the experimental rehearsal of the black drop, and the photographer's box will arrest the planet in the very act.

The consequences of Foucault's experiment, substantiated as it may be by the best astronomical evidence, are as far-reaching as the remotest stars and nebulæ. The sun's distance is the astronomer's metre, through which masses, diameters, and distances, are proportioned out to planets, comets, and stars. If the sun's distance is cut down by three per cent., there must be a general contraction in all the physical constants of the universe. The earth only is immediately

exempt from this liability. But, if, as modern science teaches, the earth lives only by the triple radiation from the sun, then an earlier doom has been written for the earth also. Geology is no longer allowed to cut its garment from the past duration of unlimited extent. The numerical estimates of physical science, with a large margin of uncertainty, assign limits between which alone geology has free play. Whatever tends to reduce or enlarge those limits must be of interest to the geologist as well as to the astronomer.

This is the brilliant career, in electricity, optics, astronomy, and geology, of the little mirror, cradled in the laboratory of Poggendorff, and which has not yet seen its fiftieth birthday.

In making this exhibit of the instrumental appliances of modern physics, I will simply name the polariscope, the stereoscope, and the instruments in photography, and hurry on to the spectroscope.

The steps by which the spectroscope has attained its preëminent rank among the instruments of the physicist and the astronomer were taken at long intervals. A whole century intervened between Newton's experiments with the prism and Wollaston's improvement. The substitution of a long and narrow slit for the round hole in the window-shutter was enough to reveal the presence of the two boldest dark lines in the solar spectrum. Wollaston stood on the threshold of a rich development in science, but neither he nor his compeers were ready for it, and what he saw, novel as it was, attracted little attention. Spectrum analysis, in relation to light itself, began when Frauenhofer published, in 1817, in the memoirs of the Bavarian Academy, an account of his experiments on the direct and reflected rays of the sun, on starlight, and various artificial sources of light, dispersing the rays by prisms of fine Munich glass and then receiving them into a theodolite. Frauenhofer repeated some of his experiments in the presence of the younger Herschel, but for many years he had the field wholly to himself. A paper by Herschel on the colors of artificial flames acquires a new interest from what has been done more recently. Between 1830 and 1860, numerous physicists, among whom are the well-known names of Brewster, Miller, Wheatstone, Powell, Stokes, Gladstone, Becquerel, Masson, Van der Willigen, Plücker, and Angström, were at work upon the facts connected with the emission of light by incandescent bodies and its absorption by gases and vapors. As early as 1830, Simms had placed a lens in front of the prism, with the slit in the focus, and another lens behind the prism to form an image of the slit.

The first hint of that pregnant fact, the reversal of the bright spectrum-bands of flames, came from Foucault in 1849. His experiment was repeated at Paris, in 1850, in the presence of Sir William Thomson. It was reserved for a young physicist of Heidelberg, who was not born until seven years after Frauenhofer laid the foundations, to place the keystone upon the structure on which many hands had

labored, by demonstrating, in 1860, the law which is the theoretical basis of the chemistry of the heavens. Kirchhoff, with admirable frankness, is careful to say that this law had been anticipated by others, especially by Angström and Balfour Stewart, although it had not been sharply stated or severely proved. It is a singular fact that the mechanical explanation of the law, as it has been expounded by Kirchhoff, Angström, and Stokes, was partially enunciated one hundred years ago by the mathematician Euler, when he said that every substance absorbs light of the special wave-length which corresponds to the vibration of its smallest particles. The 11th of July, 1861, will be ever memorable in the history of science as being the day on which Magnus read, before the Berlin Academy, Kirchhoff's memoir on the chemical constitution of the sun's atmosphere, and the existence in it of familiar substances found upon the earth. Speedily, spectroscopes were multiplied, modified, and improved, and became indispensable auxiliaries in the workshop, the laboratory, and the observatory. It is not necessary to enlarge upon what this instrument has done for common chemistry, in hunting out the minutest traces of common substances and detecting new ones. The physician, the physiologist, the zoölogist, the botanist, and the technologist, have shared with the chemist and the physicist the services of this powerful analyst. But it is the highest prerogative of the spectroscope to be able to make a chemical analysis of celestial bodies, upon the single condition that they give to it their light. Polarization can only say whether any portion of this light is reflected. The motions which the telescope uncovers may decide in favor of a central attraction, but it is silent as to the intensity of this attraction unless the moving body belongs to the solar system. The universality of a gravitation may be proved, but not the universality of the very gravitation which pervades our own system, except by an argument from analogy. We see that one star differs from another star in glory. But what the other differences or resemblances are we know not, without the spectroscope. Henceforth astronomy possesses a new instrument of discovery, and also a new tribunal to which all speculations about the sun and the stars, the aurora and the zodiacal light, the meteors and the comets, must be brought and by which they must be judged.

I leave it to the naturalists to assign a value to the alleged anticipations of Darwin by the geometer Maupertuis, who was said to have died just before he was going to make monkeys talk. The whims and conceit of Lord Monboddo are not worthy of notice. Lamarck began life as a soldier, was a meteorologist as far and as long as Napoleon would allow him to be; perhaps he was a botanist from choice, but he was made a zoölogist, in spite of himself, by the revolutionary Convention. He was as brave in science as in war; but he expected to *create* it, by a simple effort of thought. Having demolished the modern chemistry, he turned his iconoclastic zeal into natural history.

His philosophy of zoölogy was published a few years after the cosmogony of Laplace; in which the mathematician broaches the theory of evolution as a mechanical doctrine, capable of explaining certain characteristics of the solar system, about which the law of gravitation is silent. Whoever reads the stately chapters of Laplace, on the stability of the planets and the safeguards of the comets, will easily recognize expressions which are the mechanical equivalents of the principles of natural selection and the survival of the fittest. The elder Herschel hazarded the speculation that the clusters of stars and the nebulæ which his devouring telescope had picked up, by hundreds, on the verge of the visible heavens, were genuine suns assembled under the organizing power of gravitation; and that the varieties in size, shape, and texture, were produced by differences of age and distance. The imagination of Herschel and other astronomers has taken a loftier flight. To them many of the nebulæ are not clusters of stars, but unborn solar systems, waiting for that consolidation by which planets are evolved and a central sun is formed, and destined thus to repeat the cosmogony of the home system. Comte claims that he has raised the nebular hypothesis to the rank of positive science. He supposes the stupendous enginery of evolution to be reversed. He follows, with his mathematics, the expanding sun backward into chaos, until it has absorbed into its bosom even the first-born among the planets, and finds, at every stage, numerical confirmation of what Laplace threw out as a plausible conjecture. As Mr. Mill and other writers of note have accepted this authority, it should be understood that Comte has never published the data or the process of his computations. By whatever other inspiration he arrived at his conclusion, he was not brought to it by his mathematics. He has said all that is necessary to show that he ignored all the difficulties of the problem, and dodged the only solution that could give satisfaction. The cosmogony of Laplace, with all its fascination, must be excluded from exact mechanics and remanded back to its original place in natural history, by the side of the more general nebular hypothesis of Herschel. All other cosmogonies which poetry or science have invented are childish in comparison with this; and no one would desire to banish it from science altogether, until it is disproved or displaced by something better. Instead of *deciding*, it must *share* the fate of the all-embracing cosmical speculation of Halley. How uncertain that fate is we may be taught by the frequency with which the preponderance of evidence has shifted from one side to the other, during the last fifty years. The irresolvability of many of the nebulæ, by powerful telescopes, led Herschel to espouse the cause of a diffuse primeval matter, out of which worlds were fashioned. No wonder that, in particular cases, the negative evidence was sometimes turned into positive evidence on the other side, by improvements in telescopes. Although every nebula which deserted from the nebular hypothesis strengthened the suspicion that

the remaining irresolvability was purely optical, a sufficient amount of negative evidence would probably have always existed to create more than a doubt in the minds of many astronomers. On the discovery of spectrum analysis, observers rallied around it, in the hope of finding an escape from the dilemma; and this new hope has not been disappointed. The continuous spectra of some nebulæ prove them to be suns, enveloped in more or less of atmosphere. The broken spectra of other nebulæ show that they are in the condition of an incandescent gas. The classification which the spectroscope makes of the nebulæ corresponds so well with their telescopic appearance as to justify the confidence which one class of astronomers had in their way of deciding on the truth of the nebular hypothesis. While the spectroscope has manifested varieties of material, color, temperature, and consolidation in nebulæ and stars, both single and composite, beyond any thing which the perfected telescope could ever have revealed, it has at the same time found enough of earth in all of them to make man feel at home anywhere in the visible universe. The fact that certain well-known substances on this planet pass current everywhere in Nature, leads irresistibly to the conclusion that all the specimens came originally from the same mint. It is the legitimate office of science to reduce the more complex to the simple; to explain, if possible, the existing state of matter by an anterior state. The nebular hypothesis, which attempts to do this, no longer starts from a conjecture but a reality, viz., the existence of diffused incandescent vapor; and science will hold on to it, until a better theory of mechanical development is found.

An interesting question, which has waited thousands of years even to be asked, and may wait still longer for an all-sufficient answer, relates to the motion of what were once called the fixed stars. If numbers count for any thing, this is the grandest problem which can be presented to the mind of the astronomer. The argument from probabilities, which reposes on a substantial mathematical foundation, is loud in affirming some kind of motion, and repudiates the notion of absolute rest. We must place the stars outside the pale of science, and where no process of reasoning can reach them, or we must suppose that they subscribe to the universal law of all matter which we know, and exert attractive or repulsive forces upon each other. There may be one solitary body, or more probably an ideal point of space, the centre of gravity of the material universe, around which there is equilibrium, but everywhere else there must be motion. Though distance may reduce the effect of each one of the forces to a minimum, in the aggregate their influence will not be insignificant. The sun must share the common lot of the stars unless we repeat the folly of ancestral science, at which we now smile, and transfer the throne of the heaven of matter from the earth to the centre of our own little system. If the sun move, a new order of parallactic motion springs

up in sidereal astronomy. The process of elimination requires the mathematician to calculate the direction and velocity of the motion of the sun which will leave behind it the smallest unexplained residuum; and this remainder is the motion of the stars themselves. The delicacy of the problem lies in the minuteness of the quantities to be observed, and in the assumptions which must be made in regard to the distances of the stars, only a few of which have been positively computed from parallax. However, a result has been reached, highly probable in the sun's case, but which can be converted into absolute values for other stars only so fast as their individual distances are discovered. Here, again, physics and chemistry, with the spectroscope in hand, have come to the aid of astronomy and geometry. Should it appear that the conclusions from spectrum analysis must be questioned, the attempt was brave, and even a defeat would be honorable.

In 1675 a Danish astronomer observed the novel fact that the frequency in the eclipses of Jupiter's satellites fluctuated with the motion of the planet to or from the earth. He hit upon a happy explanation, viz., that the swift light takes more or less time to telegraph the astronomical news across the omnipresent lines of force. This early observation is the *avant-coureur* of a host of others which have slowly followed in close array. That of a blind musician comes next. He noticed, in 1835, that the pitch of a steam-whistle, on the Lowell Railroad, fell suddenly as the locomotive passed him. Unfortunately, Munroe's observation was never published, although he sought and found an explanation of what was then a strange fact. In this case, the whistle sends the message, the waves of sound transmit it, and the ear is the register; but the changing distance modifies the time. In 1842, Doppler, of Prague, was led, by theoretical considerations, to formulate the proposition, now known in science as Doppler's principle: that the color of light and the pitch of sound, as they tell upon the senses, are changed by the relative velocity of the observer and the origin of the disturbance. In 1845, Buy Ballot made experiments upon the railroads in the Netherlands, and Scott Russell repeated them on English railroads, which confirmed the theory in the case of sound. In the application of the theory to color, few astronomers will be willing to follow Doppler in all his extravagances.

If it be true, theoretically, that the relative velocity of light, the wave-length of transmission, and the period of oscillation in the ether, are altered by the relative motion of the observer and the place from which the undulation starts, it is obvious that all other velocities have but a small chance in competition with the velocity of light, and that slight changes of color, if physically real as Doppler supposed, would fail of being recognized even by the eye of a painter. To interpose the spectroscope, and observe the change of refrangibility by the displacement of the sharp lines of the spectrum, was a lucky escape from this embarrassment. After Huggins had tried his hand at this new

method, with a small telescope, upon the brightest of all the stars, he was supplied by the Royal Society of London with a larger instrument to pursue the investigation. The results of his spectroscopic inquiry into the motions of many stars have been published. Where these results have conflicted with the foregone conclusions of astronomy, Huggins has not hesitated to arraign the accuracy of astronomical data and methods. I have freely admitted the delicacy and difficulty of the geometrical process. The spectroscopic analysis, when applied to the same problem, walks upon slippery ground and must take heed lest it also fall. The alleged displacement is a nice quantity, and instrumental sources of error have been pointed out which may explain away the whole of it. I lay no stress upon the large difference between Vogel and Huggins in the *quantity* of motion which spectrum analysis ascribes to Sirius, inasmuch as the direction of the motion is the same. We do not yet know all the elements which the earth contains. The spectroscope has already added four to the number. There is reason to think that the stars, though having some substances in common with the earth and sun, are not without their peculiarities. The lines in the stellar spectra may be out of position, not because they are the displaced lines of sodium, magnesium, and hydrogen, but in consequence of novelties in the gaseous atmospheres of the stars. Still, there will be a presumption, perhaps a probability, in favor of Huggins's deduction, if it rests on a sound basis of theory. If there is any weakness in the physical and mathematical foundation of his argument, gratifying as it is to the imagination and the aspirations of science, the whole superstructure must fall.

THE EARLY STUDY OF GEOGRAPHY.[1]

By Major WILSON.

BEFORE concluding this portion of my address, I would draw your attention to the appliances used in the minor schools of this country for teaching geography, as they would seem to need some improvement. The appliances to which I allude are models or relief maps, wall maps, atlases, and globes. The use of models as a means of conveying geographical instruction has been too much neglected in our schools. If any one considers the difficulty a pupil has in understanding the drawing of a steam-engine, and the ease with which he grasps the meaning of the working model, and how from studying the model and comparing it with the drawing he gradually learns to comprehend the latter, he will see that a model of ground may be used in

[1] From the Opening Address of the President of the Geographical Section of the British Association.

a similar manner to teach the reading of a map of the same area. Relief maps of large areas on a small scale have their uses, but they are unsuitable for educational purposes on account of the manner in which heights must be exaggerated to make them appear at all; this objection, however, does not apply to models of limited areas on a sufficient scale, which always give a truthful and effective representation of the ground. One reason why models have not been more used has been their cost, but the means of constructing them with ease, rapidity, and at slight expense, are quickly accumulating as the six-inch contoured sheets of the Ordnance Survey are published. Instruction in geography should begin at home; and I would suggest that, as the six-inch survey progresses, each decent school throughout the country should be provided with a model and a map of the district in which it is situated. If this were done, the pupils would soon learn to read the model, and, having once succeeded in doing this, it would not be long before they were able to understand the conventional manner in which topographical features are represented on a plane surface, and acquire the power of reading not only the map of their own neighborhood, but any map which was placed before them. In our wall maps I think we have been too much inclined to pay attention to the boundaries of countries, and to neglect the general features of the ground. It is difficult to say whether the maps have followed the teachers or the teachers the maps, but I fear instruction in physical geography too often comes after that in political geography, instead of a knowledge of the latter being based on a knowledge of the physical features of the earth. My meaning may perhaps be explained by reference to a wall map probably well known to every one, that of Palestine, which frequently disfigures rather than ornaments the walls of our schoolrooms. In this map there are usually deep shades of red, yellow, and green, to distinguish the districts of Judea, Samaria, and Galilee, and perhaps another color for the Trans-Jordanic region, with a number of Bible names inserted on the surface, while the natural features are quite subordinate, and sometimes not even indicated. There is perhaps no book that bears the impress of the country in which it was written so strongly as the Bible; but it is quite impossible for a teacher to enable his pupils to realize what that country is with the maps at present at his disposal. The first object of a wall map should be to show the geographical features of countries, not their boundaries, and for this purpose details should be omitted, and the grander features have special attention paid to them. In school atlases the same fault may be traced, physical features being too often made subordinate to political divisions; and there is also, in many cases, a tendency to overcrowd the maps with a multitude of names which only serve to confuse the pupil and divert his attention from the main points. The use of globes in our schools should be encouraged as much as possible, as there are many physical phenomena

which cannot well be explained without them, and they offer far better means of conveying a knowledge of the relative positions of the various countries, seas, etc., than any maps. The great expense of globes has hitherto prevented their very general use, but some experiments are at present being made with a view to lessening the cost of the construction, which it is hoped may be successful. I cannot pass from this subject without alluding to that class of maps which gives life to the large volumes of statistics which are accumulating with such rapidity. On the Continent these maps are employed to an extent unknown in this country, both for purposes of reference and education, and they convey their information in a simple and effective manner.

THE TRANSIT OF VENUS.

By Prof. S. P. LANGLEY,
OF THE ALLEGHANY OBSERVATORY.

ON the 8th day of the present month, at a little before nine in the evening of our time, the planet Venus will be first seen entering upon the face of the sun, from that side of the earth on which it is then day, and to observe the event astronomers will have made their way from all the principal countries of the civilized world. The spectacle in itself offers nothing that is imposing; to the naked eye, indeed, nothing of it will be visible, and all that the best telescope can discern will be a small, black, circular spot moving across the upper part of the solar disk, during some four and a half hours. The interest of the occasion, as all know, lies in the rare opportunity it offers for obtaining the sun's distance from the earth; but, as it is not so well understood why this distance is wanted, why it has not been found before, and what Venus has to do with determining it now, it is proposed here to attempt to answer such questions, as fully as it can be done in general and untechnical terms, and in a single article.

The exact object to be obtained can be better understood after considering what we know about the relations of the sun and planets, and what we have yet to learn. We know already, then, with almost entire exactness, the *relative* distances from the sun of every planet (the earth included), so that, if we wished to make a map of the solar system, on which the position of each member should be laid down with great precision, we have already all the means at hand to do it. Let us suppose such a map to be drawn, in which circles around a central point represent the planetary orbits. Then the planets being ranged in a line from the sun, and the distance of Venus from it being let us say five inches, that of the earth will be seven, and that of

Mars over ten, whence we observe that Venus is our nearest neighbor, and her distance from the sun two and a half times ours from her.

As round numbers are given only for simplicity, and as we could in fact draw such a map, with the actual elliptic orbits, in which no error would exist which a microscope could detect, it may be asked, "What more can be wanted?"

But there is a most important want unsupplied: our map has no *scale*, and we do not know how much an inch on it represents in actual distance. Our case, then, is like that of a person with an accurate chart of his country before him, from which he wants to find his distance from the capital. If it have no scale attached, or an erroneous one (and the latter is our own case), he cannot measure a single distance upon it.

If, however, he can ascertain the actual number of miles between *any* two points of the map, he will plainly know what an inch on it stands for, and thus be able to construct the lacking scale; and so we, if we can measure the distance between *any* two primary planets, or between any one of them (such as the earth) and the sun, have got at the same time the means of determining *all* the dimensions of the solar system.

A determination of the distance of any remote object, which we can see but cannot reach, whether celestial or terrestrial, the sun or a mountain-top, requires that we should know either its size and the angle it fills to the eye, or else how much the direction in which we see it changes, as we change our own position by a known amount. Thus, in the latter case, a surveyor, who wishes to determine his distance from an inaccessible object of unknown size, sends an assistant to hold up a staff at the end of a line measured on the ground by a chain. First he notes, with an instrument for the purpose, the direction in which the object is seen as compared with that of the staff, and then, the assistant and observer changing places, the latter notes again the direction from the second point of view, and this will enable him to calculate the distance desired. That first found by direct measurement with the chain is called the "base-line," and it ought to be considerable when the object is far away, since in that case its direction will not, evidently, be much altered, without a corresponding alteration in the observer's position. This difference of direction, caused by a changed point of view, is called by astronomers *parallax;* nearly the only professional term with which the reader need be troubled, but one which should be clearly understood.

The principle involved in the method is probably familiar to him already, but it is here recalled, to point out how its application must be modified in finding the distance of the sun. As the earth sweeps round that far-distant controller of her path, we can send no messenger in advance along our orbit to distinguish the place we shall move

to later; we can leave no mark behind to denote the point in the void of space the earth has quitted. Our motion round the sun is therefore no help in finding its distance, and we may, in fact, for the sake of simplicity in illustration, treat the earth as standing still in its orbit, since the essential difficulty is thus nowise heightened. This difficulty, arising from the want of a proper base-line, is similar in degree and kind to that a surveyor would labor under, if he were called on to measure the distance of an object of unknown size at least half a mile away, without moving from his place. Success under such circumstances may well seem, not so much difficult as impossible; yet this is a fair simile of the apparent impracticability of measuring the distance of the sun without stepping beyond the limits of our little earth, a body so small by comparison with the sun's remoteness that, to an observer at that distance, a three-cent piece, held one hundred and fifty yards from the eye, would completely cover our globe and hide it from his view.

Within such narrow bounds we must work, or not work at all, and the reader, if he have not, from what he has just read, gained a definite conception of the principle on which all such distance measurement rests, may find aid in a very simple experiment. If any small object, such as a pencil, be held in front of the eyes as near as it can be conveniently seen, we may easily note the point on the opposite side of the room which it appears to cover, as viewed first by the right eye and then by the left. Though itself unmoved, it will appear to shift its place on the wall, when the latter is distant, in a notable degree, owing both to the difference of direction under which either eye views it, and the remoteness of the background, and the amount of this shifting will diminish progressively as it is carried directly away from the eyes, owing to its being now seen more nearly in the same direction by both, and to its approach to the wall. The change of *direction* is due to the distance from the eyes only, but, this being constant, the amount of its displacement on the wall is due only to the distance of the latter, as is easily proved by walking toward it.

The distance of the wall might conceivably be reckoned without going to it, by preparing tables which should show how this distance was proportioned to the apparent motion of the pencil on it, since one of these things evidently depends on the other, or which should tell the distance of the pencil, by the difference of direction under which we saw it. Such are the trigonometrical tables in common use, which give the distance when this change of direction and place is known. But this change as viewed by one eye or the other is the *parallax* of the pencil, the known distance between the eyes being a little "base-line," which plays the same part as the surveyor's longer one; and now, if we suppose ourselves in possession of tables which give the distance of any object, directly its parallax is known, we may substitute the earth for the head, two observers as far apart on it as they

can get for the eyes, the sun's face for the wall, and Venus for the pencil, with a better idea of the way in which her coming between us and the sun will help to find how far off it is.

By the sun's horizontal parallax is meant that particular amount of change in its direction which would be noted by our two observers if they were half the diameter of the earth apart (as in Fig. 1, where the observer at *A* sees *V* in the direction *A B*, the one at *C* in the direction *C D*, and where the difference of these directions is *A V C*, the angle under which the earth's radius would be seen from *V*). At the

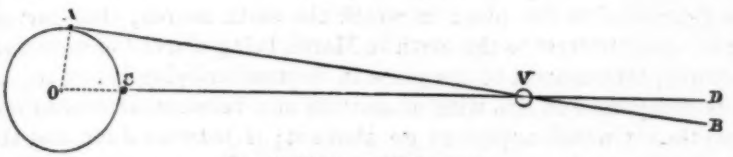

FIG. 1.—HORIZONTAL PARALLAX.

risk of needless repetition, the reader is again asked to keep in mind that, finding an object's distance and finding its parallax are convertible terms: that when the latter is large it is easily got, and implies a short distance; that when small, it is found with difficulty, and implies great distance, and that the solar horizontal parallax is almost immeasurably small—less, whatever it is, than an angle of 9.″, or than that which would be filled by a human hair over five feet from the eye. It was an error of one-thirtieth part of this last—an error less, that is, than a literal hair's-breadth *seen fifty yards off*—which caused the mistake of 3,000,000 miles, now known to have been made in measuring the sun's distance in 1769; and, if the reader has heard such a mistake cited to the discredit of astronomy, he is now in a position to judge of the justice of the reproach. It may be added, in the words of Sir John Herschel: "Moreover, this error has been detected, and the correction applied, and the detection and correction have originated with the friends, and not the enemies, of science."

If we briefly review the history of human effort at this problem, we find it occupying the mind of the ancient philosophy as well as the modern. Ptolemy, following Hipparchus, estimated, by an unreliable method, the solar parallax at 3.′, or its distance at 1,210 semi-diameters of the earth; and this grossly erroneous value remained unimproved to the time of Kepler, with whose age modern astronomy begins. Kepler having, by life-long study, discovered a means of obtaining the proportionate distances of the planets from the sun, saw clearly that this led to a new *method* of findiug its absolute distance; since, whatever it is, it stands in a known relation to that of Venus and Mars, either of which is easier found, owing to the comparative nearness of these planets, when in a line with the earth and sun. Venus, at this time, commonly passes above or below the sun, and in either

case is lost in the surrounding brightness. Kepler left the suggestion, therefore, of the use of the latter's *transit*, for the benefit of the future generation in which it should occur. The parallax even of Mars turned out to be, with the means of that day, immeasurably small; but he reached from this the conclusion that the sun's still unknown distance was, at any rate, not less than 13,000,000 miles.

To see how it is that transits are so rare, we may consider the annexed diagram (Fig. 2), where the outer circle shows the orbit of the earth, and her positions in March, June, September, and December. The orbit of Venus, lying within this, would need to be represented by a ring, inclined to the plane in which the earth moves; that part of Venus's path nearest to the earth in March being above the surface of the paper, that nearest to our place in September being below it. If the planet passed in line with us and the sun between December and June, then it would appear to go above it; if between June and the following December, below it. There are two days in each year when we are crossing the line in which the planes of the two orbits cut each other. At these times the path of Venus, if it were a visible ring, would be seen like a slanting line on the sun; but, as the planet may be anywhere else *on* her path (as, for instance, at V_2), it is evidently only under a rare conjunction of favoring circumstances that we see her passage across the sun's face (at V_1), as a black circle on a brilliant background. This phenomenon, which can only, as appears from what has been said, occur in June and December, is known as the TRANSIT OF VENUS.

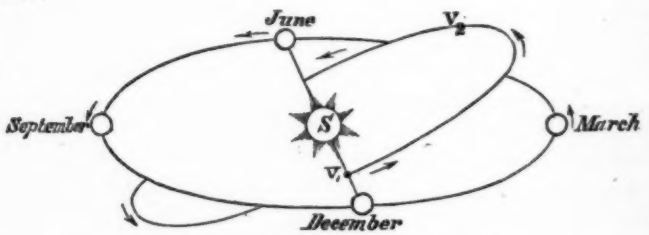

FIG. 2.—ORBITS OF VENUS AND THE EARTH.

Owing to the fact that Venus makes about thirteen revolutions in eight years, her transits frequently come in pairs eight years apart, though with an interval of over a century from one pair to the next; and thus transits have occurred in December, 1631 and 1639, in June, 1761 and 1769, and will occur in December, 1874 and 1882. That of 1631, though predicted by Kepler, passed unobserved; that of 1639 was the first known to have been seen by any one, and the circumstances of this epoch in the history of our subject deserve mention.

Jeremiah Horrocks, a young man, devoted to astronomical studies, though without counsel or support, had found from his own computations that a transit was likely to occur, though none had been looked

for by others. He had time only to warn a friend of the expected event, then close at hand, and prepared himself to observe it, by forming, through a small aperture in a darkened room, an image of the sun upon a sheet of paper. This he watched continuously on the important day, a Sunday, till the time came for church. Though knowing that the opportunity, which would not occur again to any one then living, might pass in his absence, he left it for what he deemed a religious duty, and did not resume his observation till late in the afternoon. "At this time," said he, "an opening in the clouds, which rendered the sun distinctly visible, seemed as if Divine Providence encouraged my aspirations, when, *oh, most gratifying spectacle! the object of so many earnest wishes!* I perceived a new spot of unusual magnitude and perfectly round, which had just entered on the left limb of the sun." His friend had been equally fortunate, "and thus," says Mr. Grant, in his "History of Physical Astronomy," whence this account is taken, "did two young men, cultivating astronomy together in a state of complete seclusion in one of the northern counties of England, enjoy the privilege of witnessing a phenomenon which human eyes had never before beheld, and which no one was destined again to see till more than a hundred years had passed away." Horrocks attempted to obtain the sun's parallax, but without much success; good results from such observations requiring, as will be inferred from what has been said, to be made by a *pair* of observers removed from each other, nearly as far as the limits of the earth will allow.

In 1761 and 1769 astronomers were fully aware of the importance of the occasion. Special preparations were made by different European governments, especially for the latter year, when parties were sent, as now, to various portions of the illuminated hemisphere of the globe. Among the names of those employed are the familiar ones of Captain Cook, who made his first voyage to Tahiti for this purpose, and of Mason and Dixon, the surveyors of the "line" which bore their name, and which was once so frequently heard of in our own affairs.

One, who is less known, but whose singularly bad luck deserves sympathy, was Le Gentil. Sailing for Pondicherry, where he expected to observe the transit of 1761, he was unable to land, and got no other observations than such as could be made at sea. A voyage from Europe to the Indies in those days was something so formidable, that Le Gentil, who was resolved to see the transit of 1769, decided on waiting for it abroad through eight years of voluntary exile, but, by a cruelly hard fortune, when the long-expected day came, the sun was shut out from his view by clouds which had left the sky clear till the eventful occasion.

It is perhaps worth while to recall such a disappointment, to remind us that all the skill, means, and labor, which have gone to fit out the expeditions now absent, are equally liable to frustration by

causes beyond human control; a contingency very remote, however, as affecting the entirety of the observers, and from which it is to be heartily hoped all will be exempted.

The results of the transit of 1769 were rendered uncertain, to some extent, by a curious attendant phenomenon called "the black drop," consisting in an apparent clinging of the planet to the limb, to which it is seemingly attached by a black ligament. The exact cause of this illusion is not quite agreed on, but there can be little doubt that it is in part a product of bad definition and inferior telescopes, and, as such, need be expected to give less trouble in our present observations of the times when the planet is really in contact with the edge. It may, however, cause an error of some seconds in noting the time, and in this particular seconds are all-important. Encke, who discussed these results, found from them that the parallax was 8.″56, a value always known to be questionable; but whence the sun's distance of "95,000,000 miles," which found a place in our school-books, was derived.

Within a few years past, it has become certain, by evidence from various quarters, that this is too much. Till toward the close of the last century, astronomers had no other means of finding the sun's distance than by observations on Venus and Mars; though, from those of the latter planet, indeed, a much closer approximation to the solar parallax than Kepler's value had long been obtained. Chiefly during the present century, other methods have been added, of which the most remarkable is that due to the French academician, Foucault.

Though the speed of the earth in its orbit, and that of light, were both unknown, yet the ratio of these two velocities had long been ascertained. From the assumed distance of the sun above given (95,000,000 miles), it was evidently possible to tell the circumference of the earth's orbit, and thence to say how many miles it went in a year, or a second, and, by a simple multiplication, a value for the velocity of light was obtained; since, as has just been said, the latter velocity bore a known proportion to the former. In this way, the value of 192,000 miles per second for the speed of light was found—a quantity which, being derived from an assumed distance of the sun, could not, of course, be used in turn to determine it. When, however, Foucault actually *measured* the velocity of light by a direct physical experiment, it became possible, by a reversal of the above process, to say how far the earth moved in a second; whence we learn how far it moves in a year, or, in other words, the length of its annual path; whence, again, the distance across it and the sun's distance obviously follow, the latter being thus found to be 92,260,000 miles, instead of 95,000,000.

From a discussion of all the different methods, Prof. Newcomb has concluded that the solar parallax cannot be far from 8″.85; while Mr. Stone, from a rediscussion of the results of the transit of 1769, be-

lieves that it is nearer 8″.91. The first value corresponds to a distance of 92,380,000 miles, the second to one of 91,730,000. It follows that we have heretofore made an error of about three per cent. in estimating the distances, and about ten per cent. in estimating the masses of the solar system. Neither authority regards his result as more than approximative, Prof. Newcomb, for instance, considering that his own may, as likely as not, be over a hundred thousand miles from the truth.

We get no idea from these large-sounding numbers of the all but inconceivable minuteness of the error of observation which would cause them; and such a measure of uncertainty, far from casting any discredit on the exactness of modern astronomy, is an evidence of its surprising advance toward absolute truth. Modern astronomy began with the age of Kepler; but, while the angle which represents the error in the parallax Kepler found, would correspond to that filled by the width of one of the pages of this magazine at a distance of 2,000 feet from the eye, the error now admitted as probable by Prof. Newcomb is represented by a less angle than that filled at the same distance by the same leaf turned *edgewise*.

Now that we have considered the delicacy of the measurements which have already been made, we are prepared to appreciate the task of those who, on the 8th of this month, are about to try to better them, and to examine the principles underlying the methods which will be actually used in the trial. To do this, we may, perhaps, here recur to a former illustration. If we suppose a person looking at a remote object—let us say a lighted window—from a distance which is quite half a mile, the distance between his eyes bears nearly the same relation to that of the light, that the distance between any two stations practically usable on the earth does to that of the sun. Accordingly, the difficulty of obtaining the sun's parallax, without moving from off the earth, is the same in degree that the observer would experience in measuring the distance of the light without moving from his place, and by means of the small virtual change of his point of view, obtained by looking at it with either eye; and it is under such all but insuperably hard conditions that astronomers will actually be working this month.

To see how Venus comes to their aid, we may represent her motion by a car moving at a uniform rate on a circular track, between the light and the observer. If the car pass across the light from left to right (as Venus crosses the sun), it will of course cut off the observer's view of the left side of the window from the left eye first, and, if the motion be slow enough, we may suppose him to note the exact time before the sight of the same point by the right eye is intercepted.

If he know from previous watching how long it takes the car to make its whole circuit of 360°, he knows from his watch, by an ob-

viously simple computation, just what part of a degree it went over in passing, or in its shadow's passing, from one eye to the other; the angle, in other words, that the distance between his eyes would appear under, *as seen from the light.* But this is the parallax of the light, and it gives him its distance at once (that between the eyes—the base-line —being known).

This suggests the principle of a method of obtaining the sun's parallax, on which the English astronomers will largely rely.

For, neglecting matters of detail, and supposing Venus to pass centrally across the sun, since she completes her revolution of 360° in 225 days, nearly, we find, on dividing 360° by the number of minutes in that period, that in one minute she moves through an arc of 4.″, and dividing 360° by the number of minutes in our year, that the earth moves through 2″.46 in the same time. Hence, as Venus is gaining 1″.54 every minute, the case is the same as though the earth stood still, and the shadow of Venus (could she throw one so far) passed over the earth at that rate *as seen from the sun.*

Suppose an observer on the left or eastern side of the globe had his view of part of the left side of the sun intercepted by the interior planet at nine o'clock, and one placed opposite the centre of the globe (at half the earth's diameter west of the first), five and three-quarter minutes later, then, since $5\frac{3}{4}$ times 1″.54 is 8″.85, this angle 8″.85 represents the difference of directions in which the sun would be seen by the two observers, or, what is the same thing, the angle the earth's semi-diameter would fill to an eye at the sun. This is the solar parallax, and on reference to our tables we should find that such a difference of direction could only be caused by an object nearly 92,000,000 miles off. In practice, observers are not stationed at the extreme edge of the earth (as seen from the sun), because from such a station the sun itself would be seen in the horizon, where vision of it is obscured and rendered unsteady by the vapors of our atmosphere. Neither is it needful to place observers just half a diameter of the earth apart, since it is easy to allow for the effect of greater or less

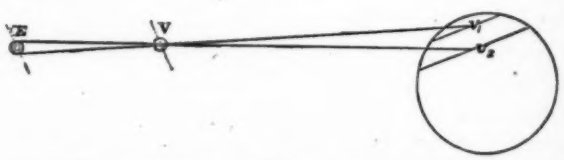

FIG. 3.—SHOWING THE DISPLACEMENT OF VENUS.

distance, and, in reality, the time would be longer than that supposed, because Venus's path lies aslant to the sun's edge, and it takes her longer to cross it. But it will, of course, be understood that such matters as these, and such complications as arise from the elliptical form of the orbits, the real inequality of the motion, the fact of the earth's

being constantly turning and changing the observers' positions whether they will or no—that such things as these, and many more, need not occupy us here, except as they suggest how excessively intricate the actual details are with which the astronomer deals.

Quite another method might be used by our imaginary observer, if we suppose him to incline his head so that one eye is higher than the other, and to be able to see over the passing car. In this case, if the lower eye had the view of the lower part of the window hidden, the other, seeing *more* over the car, would see somewhat farther down—how much farther down would be easily calculated if the proportionate distances of the car from the eyes and the window were known. This suggests a very important method for actual use in the transit; for, if we now have two stations, one in the north or upper side of the earth (upper to us, that is), the other in the south or lower side, it is clear that the upper observer, seeing more *over* Venus, so to speak, will see it as it crosses the sun at V_2, nearer the centre than the observer who is in the south, and who sees it at V_1. (Fig. 3).

If the northern station is 6,000 miles higher than the other, since Venus is two and a half times as far from the sun as from us, it will appear to cross nearer the centre by two and a half times 6,000, or 15,000 miles. Knowing how large an angle this 15,000 miles on the sun's face fills, we have, as it will readily be seen, the knowledge of how large an angle a line any given part of its length (such as the earth's radius) would fill as seen from this distance.

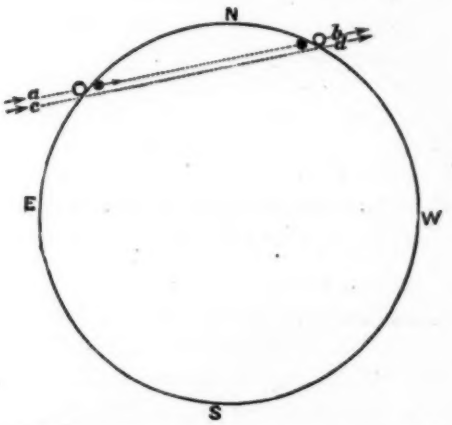

Fig 4.—Path of Venus across the Sun as seen by different Observers.

But it is immaterial whether we see such a length as the earth's radius from here, when it is supposed to be laid down on the sun, or from the sun when it is here. In either case we have got the same parallax and hence the same distance.

This apparent displacement of Venus will give us two chords of a cir-

cle (Fig. 3), the shorter one being her track to the southern observer, the longer to the northern. In Fig. 4, *a b* is her apparent path in the first case, *c d* in the second. This figure shows the direction of the planet's motion, and, with approximate truth, its apparent size as compared with the sun, and the degree of actual displacement. Its first appearance, touching the outside of the sun as at *a*, is what is called "first external contact." This is shortly followed by "first internal contact," when the planet has moved wholly on to the sun's face, and is just quitting the edge. After some four hours it touches the edge again ("second internal contact"), crosses it and disappears ("second external contact"). The external contacts have not hitherto been much relied on, but, now that with the spectroscope we can see the planet a little way off the sun, they can be better observed. The internal contacts are the important ones, and these have heretofore been rendered more or less uncertain, by the phenomenon called the "black drop," already referred to, as consisting in an optical illusion, by which the planet seems to cling to the limb and pull out of shape, like a drop of ink just about falling from the pen. (Fig. 5.)

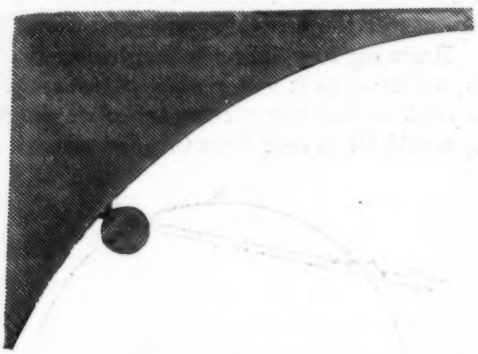

FIG. 5.—A PORTION OF THE SUN AT FIRST INTERNAL CONTACT OF VENUS, SHOWING THE "BLACK-DROP."

Since there is no actual track left to reckon the distance between the chords from, the northern and southern observers *time* the planet across, very accurately, and, from the times, the lengths of these chords, and hence the distance between them, may plainly be found, since we know just how long the planet would take to go over the sun's diameter. There is another way, by measuring the distance, from the sun's centre, of Venus at different stages of her progress, as seen by a pair or any number of pairs of observers; but probably best of all is photography, which is to be used by nearly every station, and which will give us almost any number of pictures (as many as 150 or 200 to a station), showing exactly how the planet looked from minute to minute to the photographer's lens—an observer which does not get flur-

ried, is perfectly impartial, and whose observations take the form of an instantaneous but permanent record.

Preparations of the most elaborate kind have been made by the leading nations of the world for this event for years beforehand; and the side of our globe, turned sunward on the important day, will be occupied by over seventy astronomical stations. As an amicable interchange of results is to be counted on, the means for trying every method here alluded to, as well as others, will be of the amplest kind; and there is every reason to hope that they will give us a value of the sun's distance, accurate in proportion to the knowledge, energy, and skill, which have gone to furnish them.

From what has been already said, it must be abundantly plain that, unlike an eclipse of the sun, which is total over a very small area, the transit of Venus will be visible over a whole hemisphere of the earth—over more, in fact, since the rotation of our globe brings new countries into the sunlight during the hours the passage lasts, and some will see it begin who will not see it close; others see it close

FIG. 6.—EARTH, AS SEEN FROM THE SUN, DECEMBER 8TH, AT 9H. 10M., P. M., NEW YORK TIME. (First Internal Contact.)

FIG. 7.—EARTH, AS SEEN FROM THE SUN, DECEMBER 9TH, AT 1H. 13M., A. M., NEW YORK TIME. (Second Internal Contact.)

Names of American stations, as seen located in the above diagrams:

No. 1. Wladiwostock.
2. Pekin.
3. Nagasaki.
4. Hobarttown.
5. Bluff Harbor.
6. Chatham Island.
7. Kerguelen "
8. Possession "

who do not see it begin. While the transit continues, wherever the sun can be seen, there Venus will be seen on it, with the exception of the few minutes of entry, when those on the extreme left of the earth will see her before the rest, and the corresponding time of exit.

We do not see the phenomena at all in the United States, because all America is on the night side of the earth at the time, a fact made plainer by the accompanying diagrams, showing the earth as it is poised in space, viewed from the sun; first at the beginning of the

transit (to the whole earth), and again at its close, with the effects of the earth's rotation in the interval. These diagrams are made from those prepared by Mr. Proctor (to whose admirably lucid illustrations the writer is otherwise indebted), and by Mr. Hill, under the charge of Prof. Coffin, of our own "Nautical Almanac" office; and on them have been marked the eight stations occupied by American parties. The next transit, in December, 1882, will be visible, it may be observed, from beginning to end, in the United States.

On the whole, it will appear, from what has been stated, that a transit of Venus, though not the only means of determining the sun's distance, and not possessing the relative importance it once did, remains probably the best, as it is the best known, and, if it may be so called, the most classic method.

Judging from what appears to be the probable error of our best independent determinations of the solar parallax (those from Mars), and the presumption that the majority of astronomers regard those obtainable by modern methods from Venus as still better, it is no unreasonable anticipation that the probable error of the coming result will not exceed one-hundredth of a second. In other words, it may be expected to be at least an even wager that the error of angular measurement in the final result—made up, let us remember, from the independent results of observers working in distant parts of the globe—will not exceed that which would be represented by the breadth of a hair, seen at the distance of *one mile*. So slight is that error, which will seem so large when carried out in the enormous numbers which represent the distance of the sun, and those numbers still more inconceivable which represent his own distance from his brother stars.

In one of the most remarkable writings which have descended to us from ancient philosophy, the "Arenaria" of Archimedes, that geometer undertakes to show his contemporaries that it is in the power of number to reckon not only every grain of sand upon the sea-shore or even in the whole earth, but more than would fill a solid sphere extending beyond the sun; and, in the course of his demonstration, he describes to us how he attempted to find its diameter by measurements carried on with a staff and a rod, when the morning and evening mists rendered its light bearable to the eye. If the striking picture of this "Newton of the ancient world" gazing at the setting sun, to attempt, with such rude means, a portion of the task which remains unsolved after two thousand years, be recalled here, it is because it seems fittingly to remind us of the early steps of that ascent on which man's long effort has raised him to the power of questioning Nature with means of the wonderful exactness just described, and to remind us also how long human thought has rested on the great problem to which we hope this present month may bring an answer.

THE GREAT CONFLICT.[1]

By JOHN WILLIAM DRAPER, M. D., LL. D.

WHOEVER has had an opportunity of becoming acquainted with the mental condition of the intelligent classes in Europe and America, must have perceived that there is a great and rapidly-increasing departure from the public religious faith, and that, while among the more frank this divergence is not concealed, there is a far more extensive and far more dangerous secession, private and unacknowledged.

So wide-spread and so powerful is this secession, that it can neither be treated with contempt nor with punishment. It cannot be extinguished by derision, by vituperation, or by force. The time is rapidly approaching when it will give rise to serious political results.

Ecclesiastical spirit no longer inspires the policy of the world. Military fervor in behalf of faith has disappeared. Its only souvenirs are the marble effigies of crusading knights, reposing on their tombs in the silent crypts of churches.

That a crisis is impending is shown by the attitude of the great powers toward the papacy. The papacy represents the ideas and aspirations of two-thirds of the population of Europe. It insists on a political supremacy in accordance with its claims to a divine origin and mission, and a restoration of the mediæval order of things, loudly declaring that it will accept no reconciliation with modern civilization.

The antagonism we thus witness between Religion and Science is the continuation of a struggle that commenced when Christianity began to attain political power. A divine revelation must necessarily be intolerant of contradiction; it must repudiate all improvement in itself, and view with disdain that arising from the progressive intellectual development of man. But our opinions on every subject are continually liable to modification, from the irresistible advance of human knowledge.

Can we exaggerate the importance of a contention in which every thoughtful person must take part whether he will or not? In a matter so solemn as that of religion, all men, whose temporal interests are not involved in existing institutions, earnestly desire to find the truth. They seek information as to the subjects in dispute, and as to the conduct of the disputants.

The history of Science is not a mere record of isolated discoveries; it is a narrative of the conflict of two contending powers, the expansive force of the human intellect on one side, and the compression arising from traditionary faith and human interests on the other.

[1] Preface to the "History of the Conflict between Religion and Science," No. XII. of the "International Scientific Series," to be published shortly.

No one has hitherto treated the subject from this point of view. Yet from this point it presents itself to us as a living issue—in fact, as the most important of all living issues.

A few years ago, it was the politic and therefore the proper course to abstain from all allusion to this controversy, and to keep it as far as possible in the background. The tranquillity of society depends so much on the stability of its religious convictions, that no one can be justified in wantonly disturbing them. But faith is in its nature unchangeable, stationary; Science is in its nature progressive; and eventually a divergence between them, impossible to conceal, must take place. It then becomes the duty of those whose lives have made them familiar with both modes of thought, to present modestly, but firmly, their views; to compare the antagonistic pretensions calmly, impartially, philosophically. History shows that, if this be not done, social misfortunes, disastrous and enduring, will ensue. When the old mythological religion of Europe broke down under the weight of its own inconsistencies, neither the Roman emperors nor the philosophers of those times did any thing adequate for the guidance of public opinion. They left religious affairs to take their chance, and accordingly those affairs fell into the hands of ignorant and infuriated ecclesiastics, parasites, eunuchs, and slaves.

The intellectual night which settled on Europe, in consequence of that great neglect of duty, is passing away; we live in the daybreak of better things. Society is anxiously expecting light, to see in what direction it is drifting. It plainly discerns that the track along which the voyage of civilization has thus far been made, has been left; and that a new departure, on an unknown sea, has been taken.

Though deeply impressed with such thoughts, I should not have presumed to write this book, or to intrude on the public the ideas it presents, had I not made the facts with which it deals a subject of long and earnest meditation. And I have gathered a strong incentive to undertake this duty from the circumstance that a "History of the Intellectual Development of Europe," published by me several years ago, which has passed through many editions in America, and has been reprinted in numerous European languages, English, French, German, Russian, Polish, Servian, etc., is everywhere received with favor.

In collecting and arranging the materials for the volumes I published under the title of "A History of the American Civil War," a work of very great labor, I had become accustomed to the comparison of conflicting statements, the adjustment of conflicting claims. The approval with which that book has been received by the American public, a critical judge of the events considered, has inspired me with additional confidence. I had also devoted much attention to the experimental investigation of natural phenomena, and had published many well-known memoirs on such subjects. And perhaps no one can

give himself to these pursuits, and spend a large part of his life in the public teaching of science, without partaking of that love of impartiality and truth which Philosophy incites. She inspires us with a desire to dedicate our days to the good of our race, so that in the fading light of life's evening we may not, on looking back, be forced to acknowledge how unsubstantial and useless are the objects that we have pursued.

Though I have spared no pains in the composition of this book, I am very sensible how unequal it is to the subject, to do justice to which a knowledge of science, history, theology, politics, is required; every page should be alive with intelligence and glistening with facts. But then I have remembered that this is only as it were the preface, or forerunner, of a body of literature, which the events and wants of our times will call forth. We have come to the brink of a great intellectual change. Much of the frivolous reading of the present will be supplanted by a thoughtful and austere literature, vivified by endangered interests, and made fervid by ecclesiastical passion.

What I have sought to do is, to present a clear and impartial statement of the views and acts of the two contending parties. In one sense I have tried to identify myself with each, so as to comprehend thoroughly their motives; but in another and higher sense I have endeavored to stand aloof, and relate with impartiality their actions.

I therefore trust that those, who may be disposed to criticise this book, will bear in mind that its object is not to advocate the views and pretensions of either party, but to explain clearly, and without shrinking, those of both. In the management of each chaper I have usually set forth the orthodox view first, and then followed it with that of its opponents.

In thus treating the subject it has not been necessary to pay much regard to more moderate or intermediate opinions, for, though they may be intrinsically of great value, in conflicts of this kind it is not with the moderates but with the extremists that the impartial reader is mainly concerned. Their movements determine the issue.

For this reason I have had little to say respecting the two great Christian confessions, the Protestant and Greek Churches. As to the latter, it has never, since the restoration of science, arrayed itself in opposition to the advancement of knowledge. On the contrary, it has always met it with welcome. It has observed a reverential attitude to truth, from whatever quarter it might come. Recognizing the apparent discrepancies between its interpretations of revealed truth and the discoveries of science, it has always expected that satisfactory explanations and reconciliations would ensue, and in this it has not been disappointed. It would have been well for modern civilization if the Roman Church had done the same.

In speaking of Christianity, reference is generally made to the Roman Church, partly because its adherents compose the majority of

Christendom, partly because its demands are the most pretentious, and partly because it has commonly sought to enforce those demands by the civil power. None of the Protestant Churches has ever occupied a position so imperious—none has ever had such wide-spread political influence. For the most part they have been averse to constraint, and except in very few instances their opposition has not passed beyond the exciting of theological odium.

As to Science, she has never sought to ally herself to civil power. She has never attempted to throw odium or inflict social ruin on any human being. She has never subjected any one to mental torment, physical torture, least of all to death, for the purpose of upholding or promoting her ideas. She presents herself unstained by cruelties and crimes. But in the Vatican—we have only to recall the Inquisition—the hands that are now raised in appeals to the Most Merciful are crimsoned. They have been steeped in blood!

There are two modes of historical composition, the artistic and the scientific. The former implies that men give origin to events; it therefore selects some prominent individual, pictures him under a fanciful form, and makes him the hero of a romance. The latter, insisting that human affairs present an unbroken chain, in which each fact is the offspring of some preceding fact, and the parent of some subsequent fact, declares that men do not control events, but that events control men. The former gives origin to compositions, which, however much they may interest or delight us, are but a grade above novels; the latter is austere, perhaps even repulsive, for it sternly impresses us with a conviction of the irresistible dominion of law, and the insignificance of human exertions. In a subject so solemn as that to which this book is devoted, the romantic and the popular are altogether out of place. He who presumes to treat of it must fix his eye steadfastly on that chain of destiny which universal history displays; he must turn with disdain from the phantom impostures of pontiffs and statesmen and kings.

If any thing were needed to show us the untrustworthiness of artistic historical compositions, our personal experience would furnish it. How often do our most intimate friends fail to perceive the real motives of our every-day actions; how frequently they misinterpret our intentions! If this be the case in what is passing before our eyes, may we not be satisfied that it is impossible to comprehend justly the doings of persons who lived many years ago, and whom we have never seen?

In selecting and arranging the topics now to be presented, I have been guided in part by "the Confession" of the late Vatican Council, and in part by the order of events in history. Not without interest will the reader remark that the subjects offer themselves to us now as they did to the old philosophers of Greece. We still deal with the same questions about which they disputed. What is God? What

is the soul? What is the world? How is it governed? Have we any standard or criterion of truth? And the thoughtful reader will earnestly ask, "Are our solutions of these problems any better than theirs?"

The general argument of this book, then, is as follows:

I first direct attention to the origin of modern science as distinguished from ancient, by depending on observation, experiment, and mathematical discussion, instead of mere speculation, and shall show that it was a consequence of the Macedonian campaigns, which brought Asia and Europe into contact. A brief sketch of those campaigns, and of the Museum of Alexandria, illustrates its character.

Then with brevity I recall the well-known origin of Christianity, and show its advance to the attainment of imperial power, the transformation it underwent by its incorporation with paganism, the existing religion of the Roman Empire. A clear conception of its incompatibility with science caused it to suppress forcibly the Schools of Alexandria. It was constrained to this by the political necessities of its position.

The parties to the conflict thus placed, I next relate the story of their first open struggle; it is the first or Southern Reformation. The point in dispute had respect to the nature of God. It involved the rise of Mohammedanism. Its result was, that much of Asia and Africa, with the historic cities Jerusalem, Alexandria, and Carthage, were wrenched from Christendom, and the doctrine of the Unity of God established in the larger portion of what had been the Roman Empire.

This political event was followed by the restoration of science, the establishment of colleges, schools, libraries, throughout the dominions of the Arabians. Those conquerors, pressing forward rapidly in their intellectual development, rejected the anthropomorphic ideas of the nature of God remaining in their popular belief, and accepted other more philosophical ones, akin to those that had long previously been attained to in India. The result of this was a second conflict, that respecting the nature of the soul. Under the designation of Averroism, there came into prominence the theories of Emanation and Absorption. At the close of the middle ages the Inquisition succeeded in excluding those doctrines from Europe, and now the Vatican Council has formally and solemnly anathematized them.

Meantime, through the cultivation of astronomy, geography, and other sciences, correct views had been gained as to the position and relations of the earth, and as to the structure of the world; and since Religion, resting itself on what was assumed to be the proper interpretation of the Scriptures, insisted that the earth is the central and most important part of the universe, a third conflict broke out. In this Galileo led the way on the part of Science. Its issue was the overthrow of the Church on the question in dispute. Subsequently a

subordinate controversy arose respecting the age of the world, the Church insisting that it is only about six thousand years old. In this she was again overthrown.

The light of history and of science had been gradually spreading over Europe. In the sixteenth century the prestige of Roman Christianity was greatly diminished by the intellectual reverses it had experienced, and also by its political and moral condition. It was clearly seen by many pious men that Religion was not accountable for the false position in which she was found, but that the misfortune was directly traceable to the alliance she had of old contracted with Roman paganism. The obvious remedy, therefore, was a return to primitive purity. Thus arose the fourth conflict, known to us as the Reformation—the second or Northern Reformation. The special form it assumed was a contest respecting the standard or criterion of truth, whether it is to be found in the Church or in the Bible. The determination of this involved a settlement of the rights of reason, or intellectual freedom. Luther, who is the conspicuous man of the epoch, carried into effect his intention with no inconsiderable success; and at the close of the struggle it was found that Northern Europe was lost to Roman Christianity.

We are now in the midst of a controversy respecting the mode of government of the world, whether it be by incessant divine intervention, or by the operation of primordial and unchangeable law. The intellectual movement of Christendom has reached that point which Arabism had attained to in the tenth and eleventh centuries; and doctrines which were then discussed are presenting themselves again for review; such are those of Evolution, Creation, Development.

Offered under these general titles, I think it will be found that all the essential points of this great controversy are included. By grouping under these comprehensive heads the facts to be considered, and dealing with each group separately, we shall doubtless acquire clear views of their inter-connection and their historical succession. I have treated of these conflicts as nearly as I conveniently could in their proper chronological order, and, for the sake of completeness, have added chapters on—An examination of what Latin Christianity has done for modern civilization; a corresponding examination of what Science has done; the attitude of Roman Christianity in the impending conflict, as defined by the Vatican Council.

The attention of many truth-seeking persons has been so exclusively given to the details of sectarian dissensions, that the long strife, to the history of which these pages are devoted, is popularly but little known. Having tried to keep steadfastly in view the determination to write this work in an impartial spirit, to speak with respect of the contending parties, but never to conceal the truth, I commit it to the considerate judgment of the thoughtful reader.

SKETCH OF DR. J. LAWRENCE SMITH.

WE give, this month, an excellent portrait of one of the most active and accomplished of our American scientists, one who has not only extended the boundaries of knowledge by his researches in the various fields of investigation to which he has devoted himself, but who has been a missionary of science to one of the old Oriental countries, and labored successfully to diffuse its benign influences among a semi-barbarous people.

J. Lawrence Smith was born December 16, 1818, near Charleston, South Carolina. His father, Benjamin Smith, was a Virginian, who had removed to South Carolina. The subject of this brief memoir received a classical education in the Charleston College, after which he was sent to the University of Virginia. At this institution he enjoyed facilities for the indulgence of his taste in the acquisition of knowledge in that department for which he had in early life shown a decided predilection—pure mathematics. In the later part of his academic career, he devoted himself to the higher branches of physics, mixed mathematics, and chemistry, pursuing the latter somewhat in the form of a recreation.

In determining a practical pursuit in life, young Smith selected civil-engineering as a profession, and, after devoting two years to the study of its various branches, in connection with geology and mining engineering, he was employed as one of the assistant engineers on the railroad projected at that time between Charleston and Cincinnati. This pursuit not proving congenial with his scientific tastes, he turned to the study of medicine, the college of the city of Charleston at that time possessing a corps of eminent medical teachers. After studying medicine three years, Dr. Smith was graduated by the Medical College of South Carolina, after which he went to Europe, where he devoted three more years to the study of medicine. But during all this time he continued his devotion to those departments which first commanded his scientific affections. He studied physiology under Flourens and Longet; chemistry under Orfila, Dumas, and Liebig; physics under Pouillet, Desprez, and Becquerel; mineralogy and geology under Elie de Beaumont and Dufrenoy.

Dr. Smith returned to America in 1844, having already begun to earn a reputation in original scientific researches, principally in connection with the fatty bodies. His paper on Spermaceti, in 1842, at once stamped his character as an experimental inquirer.

On his return to Charleston, Dr. Smith commenced the practice of medicine, and there delivered a course of lectures on toxicology. But the State of South Carolina, needing his services as assayer of the bullion that came into commerce from the gold-fields of Georgia,

North and South Carolina, appointed him to that duty. At the same time he gave a great deal of attention to agricultural chemistry, for which he had acquired a great fondness in Liebig's laboratory, and to this were added researches in geology and mineralogy. Among the attractive features of the agricultural chemistry of his native State that early drew the attention of Dr. Smith, were the unrivaled marls on which the city of Charleston stands. These beds of fertilizers are from 110 to 310 feet deep, and are in what geologists call the Tertiary formation. They extend back more than 100 miles from Charleston. Dr. Smith was one of the first to ascertain the scientific character of this immense agricultural wealth. His paper on this subject, with the correspondence of Prof. Bailey, the great microscopist of the Military Academy of West Point, is one of much interest. He also pointed out the large amount of phosphate of lime in these marls, from which there are now obtained immense quantities of phosphatic nodules.

During these scientific labors, Prof. Smith made a valuable and thorough investigation into the meteorological conditions, character of soils, and culture, affecting the growth of cotton. The report on this subject was so valuable, that in 1846 President Buchanan appointed Prof. Smith, in response to a request of the Sultan of Turkey, to teach the Turkish agriculturists the proper method for successful management of cotton-culture in Asia Minor. On arriving in Turkey Prof. Smith was chagrined to find that an associate in the commission had induced the Turkish Government to undertake the culture of cotton near Constantinople. Prof. Smith was unwilling to associate his name with an enterprise which he felt satisfied would be a failure, and the event fully justified his judgment. Prof. Smith was on the eve of returning to America, when the Turkish Government tendered him an independent appointment, that of mining engineer, with most liberal provisions. This position he filled during four years, and he performed his duties with such signal success, that the Turkish Government heaped upon him the decorations of the empire, and very costly presents. The results of Prof. Smith's labors are a permanent advantage to the empire, and it has received ever since 1846, and continues to receive, large revenues from his discoveries of emery, chrome, ores, and coals, within the domain of Turkey. His papers on these subjects, read before learned societies, and published in the principal scientific journals of Europe and America, gave him a high position among scientific men. His labors in Asia Minor on the subject of emery, which he was the first to discover there, led to its discovery in America; and in Massachusetts and North Carolina a large industrial product of emery is now carried on. In the scientific journals of this country, the papers on emery and corundum recognize the successful researches of Prof. Smith as having done almost every thing for these commercial enterprises. These discoveries of emery in Asia Minor destroyed the rapacious monopoly of the article at Naxos, in the

Grecian Archipelago, increased the amount of emery used five or six fold, with a corresponding reduction in price. In many of the arts of life the free use of emery or corundum has become a necessity, but this free use of these articles would have been greatly retarded without a very material reduction in price.

While in the employment of the Sultan of Turkey, Prof. Smith investigated a great variety of Turkish resources, besides those directly within the purview of his appointment as mining engineer. His paper on the "Thermal Waters of Asia Minor" is one of extreme interest and great scientific value.

In 1851 Prof. Smith invented the inverted microscope, an important improvement; for, while it may do the work of any other microscope, there are very interesting fields of research which can be cultivated by no other instrument. Dr. Carpenter, in his work on "Physiology," bears strong testimony to its value.

After Prof. Smith's return from Turkey, his *Alma Mater*, the University of Virginia, elected him Professor of Chemistry, and, while discharging the duties of that chair, he, in connection with his able assistant, George J. Brush, at present one of the chief professors in the Sheffield School of Science, performed a much-needed work in revising the "Chemistry of American Minerals." A full account of these labors was given in the *American Journal of Science*, and subsequently in a valuable and interesting work containing the scientific researches of Prof. Smith, recently published by J. P. Morton & Co., in the city of Louisville.

After marrying, in Louisville, the daughter of the Hon. James Guthrie, Prof. Smith adopted that city as his home. He was elected, soon after settling in Louisville, to the chair of Chemistry in the Medical Department of the University of Louisville, a position which he held for a number of years. After resigning that chair, he took scientific charge of the gas-works of Louisville. He has a private laboratory where he spends several hours each day, and continues his devotion to original research.

Prof. Smith was one of the commissioners to the Paris Exposition of 1867, and made an able report on "The Progress and Condition of Several Departments of Industrial Chemistry." It is very nearly exhaustive of the important subjects to which it is devoted. Prof. Smith was again appointed commissioner to Vienna in 1873, and discharged his duties with his usual ability.

Prof. Smith's important original researches are no less than fifty in number, and his scientific reports are numerous, showing great activity and perseverance in cultivating the field he has chosen. Among the honors he has received is the highest that American science can confer, the presidency of the American Association for the Advancement of Science, to which he was elected in 1872.

CORRESPONDENCE.

RIVER HYDRAULICS.

To the Editor of The Popular Science Monthly:

IN the July number of THE POPULAR SCIENCE MONTHLY, there is an article entitled "The Hydraulics of Great Rivers," said to have been mainly derived from an account, in the April number of the *Edinburgh Review*, of a book called "The Paraná, the Uruguay, and the La Plata Estuaries," by M. Révy, a member of the Institute of Civil Engineers of Vienna.

In that article there were so many statements calculated to give an erroneous impression to the reader, that it seemed to me some comment was called for. These statements I will examine in turn:

"At the point near Rosario, where the river is 4,787 feet wide, a series of measurements has been made by M. Révy, which constitutes the largest measurement of a river section yet effected. . . . The average depth was 47½ feet, and the greatest 72 feet, while the sectional area measured 184,858 feet."

In the "Report upon the Physics and Hydraulics of the Mississippi River," by Captain Humphreys and Lieutenant Abbot, of the Corps of Topographical Engineers, United States Army, published by Lippincott & Co., in 1861, by authority of the War Department, there are given the dimensions of 93 cross-sections of the Mississippi River, commencing at Columbus, Ky., and extending to Fort St. Philip, some 75 miles below the city of New Orleans. Two sections, one at Osceola, Ark., the other at Randolph, Tenn., measured by Lieutenant Abbot in 1858, are, respectively, 6,880 and 6,080 feet in width, 195,844 and 184,717 square feet in area, the maximum depths being 87 and 117 feet; while four of the other sections of the Mississippi exceed 243,000 square feet in area, which M. Révy gives as the measurement of the same Rosario section during the ordinary flood. The claim, therefore, of "the largest measurement of a river-section yet effected," is hardly a valid one. The language, "largest measurement yet effected," rather gives one the idea that it is a pretty difficult matter to measure the cross-section of a large river, whereas it is a comparatively simple operation. A sounding-party in a boat, and two observers at the extremities of a carefully-measured base-line on shore with theodolites taking simultaneous observations on the sounding-boat, are all that is necessary to determine the section with great accuracy.

To quote again: "While, therefore, it is easy to measure the velocity of the surface-current, it is difficult, because of this retardation beneath, to determine the mean velocity or actual flow of the river. This has never been satisfactorily done before. Many experiments, with a view to the accomplishment of this end, have indeed been made by eminent men, but they have failed to establish the relationship between the depth of the stream and the velocity of the flow. M. Révy has established that the velocity of a river is directly proportionate to its depth, diminishing or increasing therewith."

It is indeed true that many eminent men have occupied themselves with this problem; but whether they have failed to establish the relation between the velocity and depth is another question, though they certainly failed to find the relation so extremely simple as that determined by M. Révy. In the Government publication referred to, there is an outline of the history of hydraulics applied to rivers, beginning with the contributions to the subject by Castelli, a pupil of Galileo, in 1628, and extending up to the date of the Report. And, by-the-way, Dr. Thomas Young, a portrait and biographical sketch of whom are in the same July number of THE POPULAR SCIENCE MONTHLY, was a contributor to this subject. The numerous formulæ of different investigators are given in the Report, all reduced to a uniform system of notation, but are rather too complicated to be merely copied in a letter, without the accompany-

ing remarks and discussions to render them intelligible.

Again: "It was determined by actual experiment that the greatest velocity of current is at the surface, and the least at the bottom; and that the increase of velocity 'is in the simple ratio of the distance from the bottom.'"

Taking this ratio as true, draw a vertical right line, to any convenient scale of equal parts, to represent the depth of the river at any given place. Then the velocities at different depths would be represented graphically by an inclined right line, the lower extremity coinciding with that of the vertical and the upper at a distance from the upper extremity of the vertical equal to the surface-velocity. Humphreys and Abbot did not find the relation so simple; they demonstrate that "the velocities at different depths below the surface, in a vertical plane, vary as the abscissæ of a parabola, whose axis is parallel to the water-surface," and that "the position of the axis in calm weather is about $\frac{1}{10}$ of the depth below the surface, whatever be the mean velocity of the river." In order to deduce the relation between the velocity and depth, the river-depth was divided into ten equal parts, and the velocity of each was determined by 222 observations; the mean velocity, which was 0.297 D (depth) below the surface, was 3.26 feet; the mean depth 82 feet.

Very many other points of interest are brought out in the Report; such as proving that the curve of surface-velocities is also a parabola, deducing the values of the parameters of these curves, showing how the curves are affected by winds, irregularities of the bottom, etc., etc. The conclusions were deduced from an immense number of observations taken at different times of the year, different stages of high and low river, and at numerous points, by a number of careful and trained observers. In the mathematical discussion of results, the most refined methods were employed.

The current-metre used by M. Révy, although it is stated that he improved it greatly, is open to grave objections, double floats being preferable in point of accuracy in determining the laws regulating the flow of water in river-channels. I have never used any of the patent current-metres, though I have seen and examined them; but I have used the double-floats often enough to be convinced of their utility. I have, however, used an instrument very similar in principle to the current-metre, one of the numerous patent deep-sea leads. This instrument registered depths in fathoms and quarters on an index-wheel turned by the rotation of a propeller, the latter being so arranged as to turn the index-wheel on going down, but, on being drawn up through the water, was thrown out of gear, so as not to unwind the register.

This lead I tested by over one hundred careful soundings, taken at depths ranging from six to fifty fathoms, simultaneous soundings being taken with the patent lead and an ordinary lead-line. The soundings given by the patent lead were so utterly unreliable that I discarded it, and used the ordinary lead-line for the entire work of some pretty extensive hydrographic surveys. To show that this is not merely my own individual opinion about this style of instrument, I will quote, from page 621, Report of the Chief of Engineers for 1870, the criticism of General Abbot upon the same class of instruments:

"In my opinion, founded on a somewhat close study of the subject, instruments of this class are pretty toys, which have contributed more to retard the progress of discovery in the science of river hydraulics than any other one cause. This is due principally to the fact that they register their results in a kind of cipher, to which we can by no means be sure that we possess the key. To translate a given number of revolutions of a submerged wheel into velocity per second, and by this means to detect laws whose existence is denoted only by differences of a few tenths of feet in this velocity, is so delicate an operation that errors in the coefficient have usually masked the laws."

The subject of river hydraulics is quite an intricate one, and not likely to be investigated by people generally. Therefore, an article on this subject in a magazine is apt to be read and its statements accepted with less of questioning than one upon almost any other scientific topic.

I have been a constant reader of THE

POPULAR SCIENCE MONTHLY from its commencement; I know that it has been the aim to make the science of the MONTHLY not only popular, but accurate, and that must be my apology for writing this letter.

Very respectfully yours,

CHARLES E. L. B. DAVIS,
First-Lieutenant U. S. Engineers.

EDITOR'S TABLE.

PROFESSOR NEWCOMB ON AMERICAN SCIENCE.

A NEW standard has grown up in modern times by which the advance of nations may be measured. Hitherto, military power, extent of territory, historic prestige, and commercial resources, have been taken as the chief tests of national greatness. These were old barbaric standards. But, with the progress of civilization, which means the rule of reason in human affairs or the control of society by pacific agencies, new ideals of what constitutes national grandeur are beginning to arise. The relation of nationalities to science may be looked upon as a true test of their rank. Science is an agency of human amelioration universally acknowledged, which is already powerful in shaping the course of the world's affairs; and it is certain to be more and more appealed to in future in determining the order of nationalities in the hierarchy of civilization. What is the relation of a people to science—the highest form of knowledge? How do they estimate it? What encouragement do they give to its original investigation and popular diffusion? are questions not to be neglected in our estimates of national character. How does this country rank with other countries in its appreciation of science? is a home question, which it is desirable to have clearly and decisively answered.

In an able article, entitled "Exact Science in America," published in the last number of the *North American Review*, Prof. Simon Newcomb, Superintendent of the Naval Observatory in Washington, has taken up the subject of the state of science in the United States, and brought us into comparison in this respect with foreign nations. His results are not flattering to our national vanity, and the inferior rank which we take leads him to inquire into the causes of our backwardness. We cannot do our readers a better service than to state some of Prof. Newcomb's main positions, and look a little into the question he raises as to the cause of the present state of things, and what is best to be done. So important is the subject, and so excellent its presentation, that we shall make copious extracts from the article; but we must remind the reader that these extracts are but fragments, and can give no just idea of the unity and fullness of the original statement.

Prof. Newcomb confines himself to a consideration of the state of pure or exact science, "to which we are impelled by the purely intellectual wants of our nature," and omits the applications of science to the arts of life, to which we are impelled by practical motives, and in which "we should find our country in the front ranks of progress." Beginning with mathematics, he says: "When we seek for published mathematical investigation in this country, we find hardly any thing but an utter blank. Of mathematical journals designed for original investigations, such as we find in nearly every country in Europe, we have none, and never have had any. There have been a number of short-lived attempts to establish mathematical periodicals suited to the state of science here, some of them worthy of all praise; but the necessity of adapting their contents to the capacity of their readers prevented

them from containing any thing of importance in the way of original investigation." Again: "The only place in which we can search for any thing in the shape of original contributions to mathematics is in the transactions of our learned societies; and here we find, since the Declaration of Independence, a score or two of papers professedly of this character, but it is not likely that more than one or two of them contain any thing worthy of quotation or remark. The whole of them together would not amount to so much as the mathematical journals of Europe publish in a month."

When we pass to the physical sciences, the prospect is said to be a little more encouraging. We have active workers of the highest character in experimental physics, but they are very few, and their productions small. "Here, as in every other science, we find our deficiency to increase just in proportion as the science becomes exact. Many branches of physics have attained, and nearly all the remaining branches are rapidly attaining, the mathematical stage of development. As they enter this stage, we find our American cultivators all dropping off." In exact astronomy, we have the eminent names of Bowditch and Peirce; observatories quite comparable with those of Europe, in charge of first-class men, "yet we do not find our astronomers engaging in investigations of the utmost delicacy; and the first determination of the parallax of a fixed star by an American astronomer has yet to come."

Taking scientific journals and transactions as the measure of work, we have but a solitary periodical of the first rank —*Silliman's Journal*. "Our two most active societies have been the Philosophical Society of Philadelphia, and the American Academy of Arts and Sciences, each of which has brought out about a dozen volumes of transactions since the beginning of the century. Excluding societies whose publications are purely biological, we are not aware that half a dozen other volumes of transactions have appeared within the interval alluded to. Add the eighteen volumes published by the Smithsonian Institution, itself founded by a foreigner, and we shall have a total of between forty-five and fifty volumes in three-fourths of a century. This total, combined product of the Smithsonian Institution and all the scientific societies of the country is about equal to what either the Royal Society or the French Academy of Sciences publishes in one-third the time. . . .

"The great mass of scientific papers in Europe do not, however, appear in transactions, but in scientific journals. Here we stand at a much more striking disadvantage. Against a hundred and fifty or two hundred pages annually on astronomy and physics in *Silliman's Journal*, Germany can show us two journals of pure mathematics, publishing together three or four large volumes of matter every year — two or more of mathematics and physics, one of astronomy, and one of physics and chemistry. Altogether, these journals issue ten or eleven volumes annually, half of them quarto, and half octavo."

Making allowance for a semi-popular element in English original contributions, "it is probable that, instead of finding in England, as we do in Germany, thirty or forty times as much publication of original research in exact science as in America, we should find only five or ten times as much. A comparison with France would probably be more to our disadvantage than that with England, as the *Comptes Rendus* of the French Academy alone contain ten times more matter pertaining to exact science than *Silliman's Journal* does."

In view of these results, Prof. Newcomb remarks: "Making every possible allowance, and viewing the facts from every stand-point, we shall be able to make only the most beggarly

and humiliating showing. What is yet worse, we cannot claim to be improving our relative position, but are rather falling back, scientific activity increasing more rapidly in Europe than here."

The question now arises as to the cause of this state of things. "Why, with our numerous educational institutions and our great crowd of professors, should our contributions to the exact sciences be so nearly zero?" And to this question he answers: "The real proximate cause is found in the lack of any sufficient incentive to the activity which characterizes the scientific men of other nations, and of any sufficient inducement to make young men of the highest talents engage in scientific pursuits. The reason that so much more scientific investigation is done in Germany than in this country is, simply, that the inducements to do it are there so much more powerful."

Prof. Newcomb points out that, "in Germany, the seats of scientific activity are the universities; in France and England, the learned societies;" and that, while in Germany it is the professors who make the universities, in this country it is the universities that make the professors. "Students flock to Berlin, not because the university is an old, celebrated, and good one, but to hear Helmholtz and Virchow. If all the men like these should leave the university, the students would follow them. But, in this country, students are not attracted to Harvard and Yale by the names of individual professors, but by the reputation and organization of the colleges." Professors may, perhaps, be held in as high esteem here as in Germany, but for different reasons. The question in Germany is not, How much does he know? but, What has he added to knowledge? "What has he discovered that is new? what doubts has he cleared up? what fallacies has he exposed? what increase of precision has he given to the subject he has studied?" On the contrary, in our own so-called universities, "nothing more is expected of a professor than acquaintance with a certain defined curriculum and ability to carry the student through it. He has nothing to do but to satisfy the appointing power that he understands what is found in a certain text-book, and that he can teach what he knows to others." He is not for a moment expected to be an original investigator; while, for the kind of work not required here at all, the German is held in the highest estimation, and may secure large pecuniary rewards, and a position in the affections of a large body of educated men.

In England and France, on the contrary, it is not the universities but scientific societies which furnish the incentives to research. "It is a fact which we have to face, and which it would be folly to disguise, that our scientific societies do not compare with those of England in wealth and power. . . . The great weakness of most of our scientific organizations does not, however, consist in the want of financial means, but in something much more difficult to determine and define. We can only say that, with a few exceptions, they exhibit a total lack of cohesive power, vitality, and that undefinable something which may be called weight and importance. However eminent may be the men who compose them, most of them are, as organizations, insignificant, and exhibit the same liability to die from slight causes that weak and sickly individuals do. A history of all the attempts to organize learned societies in this country would afford an instructive study in human nature, and might show that they died by causes as uniform as those which cause the decay and death of individuals. . . .

"The important fact which we wish to impress on the mind of the reader is, that, when an Englishman makes any scientific investigation or discovery of merit and importance, he is considered

a valuable member of society, and society takes pains publicly to indicate its appreciation of his value. When we say that in this country one may devote his life to science, and may gratuitously give to scientific investigation an amount of labor and talent which would secure him both wealth and distinction in any other profession, without receiving therefor a solitary public mark or expression of appreciation from any source whatever, or the slightest additional consideration from the public, hardly any thing more is necessary to show that there is here comparatively little incentive to such work."

The backwardness of science in this country is thus attributed to the lack of those incentives to its cultivation which come from public appreciation. There is talent enough, there are facilities enough, there is interest enough in research, but there is no sufficient external spur to scientific exertion. Men will not toil where their labors are unappreciated, and the general esteem of science is too low to arouse and sustain the necessary ambition in its original cultivators. Assuming this to be a correct view of the case, the question arises, What is to be done? Are we to try to repeat the experience of Europe? In European countries there has been the slow and gradual differentiation of a scientific class which has its wealthy, powerful, and venerated organizations that form a kind of scientific world, the approbation and rewards of which are sufficient to stimulate men to give their lives to research. No such class has been developed here. Our investigators are too few and widely scattered, and their associations are too weak to give inspiration and support to original work. It is a case of immaturity, and Europe has the start of us by centuries. We have tried to imitate the foreign academies and associations, but the effort is futile, for the lack is of scientific feeling—motive power to work—and that cannot be created by acts of corporation. Obviously, therefore, from the nature of our circumstances, scientific development in this country must take a different course, and connect itself with general education and public opinion. As long as we rely upon imported methods of nurture, science must languish in this country, and fall further and further behind; but when the policy of the advancement of science is made to conform to the character of our institutions, when science takes the place to which it is entitled in our system of popular education, then may we expect such an increasing appreciation of it as will give much stronger incitement to the work of original investigation. But in this matter of the popular diffusion of science it seems there has been even less interest here than abroad. Prof. Newcomb says:

"Our instrumentalities for communicating to the educated public a knowledge of the doings of the scientific world have, until very lately, been nearly as defective as our means of scientific publication, and, notwithstanding certain recent improvements, are still far behind those of other nations. In England, France, and Germany, weekly, monthly, and quarterly journals of popular science are too numerous to be recounted; while, previous to the establishment of THE POPULAR SCIENCE MONTHLY by the Appletons, we had not in this country a single journal designed to diffuse the knowledge either of general or exact science. The *American Naturalist*, as its name implies, is devoted entirely to biology. One of our principal scientific wants has been a publication which should serve as a medium of communication between scientific men and the educated public, as well as between the various classes of scientific workers."

And again: "Within the past three or four years there has been a large increase in the amount of popular scientific publication in this country, which

is seen in the establishment of a scientific magazine, and in the appearance of 'scientific columns' and 'scientific departments' in many of our newspapers and magazines. But the great object of educating the intelligent public in scientific matters is very imperfectly fulfilled by these publications. A considerable portion of the matter they present to us consists of fugitive items, hardly more interesting or important than the column of daily clippings, of one short sentence each, which has become a feature of our newspapers. The most notable exceptions have been the 'Science Department' of the *Atlantic Monthly* while it lasted; the 'Editor's Table' of THE POPULAR SCIENCE MONTHLY, and, of late, the 'Science Record' of *Harper's Magazine*. Here we have found original discussions of scientific questions, and reviews of the progress of science by competent writers. For the rest of THE POPULAR SCIENCE MONTHLY so much cannot be said. When first started, it was mostly made up of extracts from English publications, and of essays, which could hardly have found a place in any other publication. Of late, it has gradually improved by including more original matter, and that of a better class. But it has never attempted to supply the great want to which we have referred, namely, that of making known the progress of science in this country; and the reader who wishes to learn what our scientific men are doing here, will find far more copious accounts of it in *Nature*, an English periodical, than he will in the American magazines referred to."

And for this defective state of scientific journalism, by which "the great object of educating the intelligent public in scientific matters is very imperfectly fulfilled," we beg to ask, Who is mainly responsible? What have our eminent scientific men themselves done toward this important work of popular scientific education? Is it too much to say that, as a class, they have neglected it, and that many of them have repudiated it? They have left it to half-instructed men—to men without scientific position—and, when it was poorly done, have cast reproach upon their work. Some of our distinguished scientific men have indeed indulged more or less in popular lecturing, but often with vehement protests against the degradation, and obtrusive statements that they did it for the sake of the money alone. What have they attempted, in any concerted or systematic way, through associations or publications, "to educate the intelligent public into an appreciation of the importance of scientific investigation?"

Prof. Newcomb bears witness upon this point when he says that, "previous to the establishment of THE POPULAR SCIENCE MONTHLY by the Appletons, we had not in this country a single journal designed to diffuse the knowledge either of general or exact science;" that is, scientific men had contributed absolutely nothing in the way of a periodical devoted to the promotion of their own most vital interests. We showed, in the October MONTHLY, how the American Association for the Advancement of Science in its organization carefully avoided committing itself to any agencies of popular influence, and deliberately placed itself behind the British Association in this respect. If the education of the public to a better appreciation of science is the one thing needful to relieve this country from the odium of its position upon this subject, and the one thing necessary for the liberal encouragement of a scientific class, why has our leading body of scientists so studiously refrained from taking any action toward so desirable an end? The subject of general scientific education is now widely confessed to be of great public moment. The community is not only ripe for action upon it, but in the chaotic state of school instruction it is asking for light and guidance as to the

methods that shall be adopted. Help should have come from men of authority, and an expression of the American Association would have had great weight and a salutary influence with the people. Yet a committee was appointed at its Portland meeting to report upon the subject of better methods of general scientific instruction, and at the recent Hartford meeting it was discharged without having done any thing, the chairman stating that he had never even heard of his appointment! This indifference, we think, is very much to be regretted.

Prof. Newcomb says that THE POPULAR SCIENCE MONTHLY has never attempted to supply the great want of making known the progress of science in this country, and is even behind the English periodical *Nature* in this respect. It certainly was not the chief object of the establishment of this magazine to report the doings of American investigators, and this for several reasons. In the first place, the field was already occupied by a journal of high character, which, with the proceedings of scientific societies, gave this information to the class most wanting it—the students of science. Moreover, the public press has latterly entered upon the work, and is constantly seeking for scientific novelties, as matters of ordinary news. Besides, as Prof. Newcomb shows, American contributions to the progress of science are but an insignificant portion of the total work that is doing in the scientific world, of which no single periodical could give even a synopsis. Nor is it to be forgotten that an immense amount of that which is currently published as "new results" has but a momentary importance! But a small portion of such work stands the test of time. Of the score or two of original contributions to mathematics, published in the transactions of our learned societies since the Declaration of Independence, Prof. Newcomb assures us that "it is not likely that more than one or two of them contain any thing worthy of quotation or remark." With this enormous shrinkage of scientific values, we think it is quite as well that the new results should be tested, discussed, and the chaff blown away by scientific criticism, before the final product is pressed upon the general public.

But the strongest reason why the MONTHLY has not assumed the duty of reporting American scientific work is, that is was started for distinctly another object—namely, to interest the non-scientific public, and to create a taste for scientific literature, and an appreciation of scientific knowledge in the reading community. The general ignorance of science is simply deplorable! The literary culture to which general education is committed does not lead to science, but, by its exclusive claims and overshadowing influence, hinders and prevents its study, so that, among so-called intelligent people, the ignorance of scientific subjects is so gross as to give much excuse to scientific men for their contempt of the hopeless work of its popularization. Between the state of mind of learned scientific explorers and that of the mass of magazine-readers throughout the country the gulf is already wider than the Pacific Ocean, and is constantly widening. As regards science, there is very little that is common between them. But a journal which aims to influence a non-scientific public must be somewhat suited to its state of mind, or it will not be read. Were we to fill the MONTHLY with the results of laboratory processes and observatory work, or with that which most concerns investigators, it might rise in appreciation with them, but it would not be wanted by the people, as all experience with such publications has shown. The public needs rudimentary explanations much more than the "last results" of science. The theory of this periodical is, that those who write for

it shall turn their backs upon the scientific world, and address themselves to a class so uninstructed in scientific matters that every thing requires to be explained. That we have realized this ideal is not claimed; but, granting that "the great object of educating the intelligent public in scientific matters is very imperfectly fulfilled" by this publication, we have Prof. Newcomb's authority that it was not fulfilled at all by any previous periodical in this country. Our enterprise had no precedent, and, such were its obvious difficulties, that, at starting, it was generally supposed it would be a failure. We are quite aware of its shortcomings, and, thanking Prof. Newcomb for the recognition of its improvement, we hope that it will continue to grow better. But, as our pages attest, it has not been unmindful of the advances of inquiry, though it has given prominence to those extensions and widenings of scientific thought in which we believe the public has a growing interest; for the advance of science does not merely consist in new physical and chemical experiments, new mathematical solutions, or astronomical discoveries; it consists quite as much in scientific modes of thinking applied to subjects not hitherto dealt with by such methods. The great difficulty is, that the instruments, processes, problems, and general subject-matter, of advanced investigation are so completely removed from general experience; and the public interest, we think, can never be seriously enlisted in scientific inquiries until they take account of phenomena, facts, and questions, that fall within the range of familiar observation and common thought. That the public is to-day far more interested in the relations of science to religion than they are in science itself, is because one term of the relation is so thoroughly familiar to the general mind.

LITERARY NOTICES.

THE PHYSIOLOGY OF MAN: Designed to represent the Existing State of Physiological Science, as applied to the Functions of the Human Body. By AUSTIN FLINT, Jr., M. D. In Five Volumes. Volume V. Special Senses; Generation. New York: D. Appleton & Co. 517 pages. Price, $4.50.

THE fifth and concluding volume of Dr. Flint's comprehensive work on physiology is now published, and we congratulate the author upon the completion of his task and the success of its execution. We gave a brief account of the general object of the work, in noticing a previous volume, and have only now to say that the concluding book of the series not only sustains, but surpasses, the high character won by its predecessors, while the whole work—the product of eleven years' labor—is an honor to its author and a credit to the science of the country.

The literary merit of these volumes, we think, deserves especial recognition; that is, their style is admirably adapted to its purpose of conveying clear impressions to the reader with a minimum of effort on his part. To the general reader, there is necessarily a certain amount of hindrance from the use of the unfamiliar terms of the science; but, in no first-class work upon the subject, that we remember, is there so little embarrassment on this score as in that of Dr. Flint. In his style he has attained the excellence of a lucid simplicity, one of the perfections of art which is the more remarkable, as, being a laborious experimental physiologist, busy firstly and mainly with his science, he cannot have had much time to spare for literary discipline. It is a general fault with our scientists, that they too much neglect literary cultivation, and break down in the arts of statement; Dr. Flint is not open to this criticism. Hence, while his work will have an increasing value for physiological students, it has also peculiar claims on non-professional readers who may care to consult an elaborate treatise upon the subject.

In regard to the original character of the work, and its claims as a whole fairly to represent the present state of the science, the author says, in his preface:

"In the preparation of this work, the author has formed his opinions, to a great extent, from the results of direct observation and experiment, as the true basis of what is positively known in physiology; and, while the earlier volumes might be modified by the addition of new facts, they contain comparatively little that has been disproved by recent investigations. Experimental observations have been studied and criticised from a practical point of view; and in this the author's training, as an experimentalist and a public teacher for more than fifteen years, has given him a certain degree of confidence. It is the practical physiologist who is best qualified to judge of the correctness of physiological experiments, and of the accuracy of methods of investigation; and the author has learned, from his own attempts at original observation, to estimate the difficulties of direct research, and to appreciate the inaccuracies into which careless, inexperienced, or over-enthusiastic workers are liable to fall."

EVOLUTION AND PROGRESS: An Exposition and Defense. The Foundation of Evolution philosophically expounded, and its Arguments succinctly stated. By Rev. WILLIAM I. GILL, A. M. New York: Authors' Publishing Company, 30 Bond Street. 295 pages. Price, $1.50.

THIS little volume has some striking characteristics which take us somewhat by surprise. It is a prize essay of the Authors' Publishing Company, and a thoroughgoing defense of the doctrine of Evolution by a working orthodox clergyman. Its dedication is significant of the progress of catholic views, such as we hardly expected to see in this generation: "To Herbert Spencer, Esquire, and the great brotherhood of evangelical divines, the author dedicates 'Evolution and Progress,' in token that the full complement of truth must ensphere all the antipodes of thought." The volume is mainly a discussion of the principle of Evolution in its highest philosophical aspects, and the argument is conducted in the most interesting manner, by taking up the objections of its leading opponents, as Dawson, Winchell, and Bowne, and its *quasi* opponents, as Dr. Carpenter and Prof. Le Conte. The author writes from his point of view as a clergyman, not in the narrow professional sense, but as an uncompromising devotee of truth in its unity and completeness. He has his own views, and, while accepting Evolution in its broadest sense, and shrinking from none of its consequences, he yet holds it to be but a part of a larger order of philosophy yet to be worked out. In his preface, he says:

"For himself, the writer cares very little for Evolution as an ultimate system of philosophy. We think its method, so far as it goes, is philosophical, its arguments sound and logical, and its conclusions invulnerable against any thing that has yet been brought to bear against them. But we want, however, to go farther and get something broader and more profound — something that leaves intact what Evolution has disclosed, but finds it a place in a larger scheme, and ennobles it by the new and higher relations into which it is thus brought. But incomprehensive and uncomprehending dogmatism, whether for or against Evolution (for it belongs to both sides), stands in the way, and demands that progress shall be in a circle. But it is orthodox dogmatism which, on this subject, is most obstructive of progress; and it therefore requires to be startled, if not stunned, into the perception of its philosophically defenseless and helpless condition, so as to make it see a new light, and accept the offer of more effective weapons. Kant confessed that the skepticism of Hume broke the dogmatic slumbers which he was indulging on the iron bed of the Leibnitzo-Wolfian philosophy, and thus quickened the world afresh into thought. Evolution is surely destined to perform the same office more healthfully for the complacent slumberers of this age, whether physical, metaphysical, or theological slumberers. To make a small contribution toward this result, is the object of this monograph.

"There are many who are crying, 'Peace, peace!' where there is no peace; and they are healing their theological hurt slightly — daubing with untempered mortar. They bless their superannuated philosophy with the wild belief that Evolution is becoming exhausted — going off into a decline, and that it will soon die of inanition. On the contrary, it is like the mountain-stream, making fresh acquisitions, and increasing in strength and volume as it rolls; and must continue so to do till it is lost in the ocean. Evolution is now made the foundation of religious rationalism in England and America; and the best foundation it has ever had — one which can easily be exhibited to the com-

mon people; and the 'liberal' pulpit is becoming fervent and attractive in its efforts to show how the Gospel can be and should be accommodated to Spencerianism, and how this system furnishes the best philosophy of religion. Practically, therefore, it is not to be ignored and pooh-poohed, or treated with indifference by the evangelicals, as some of them affect to do. Never was thought so active as it is to-day, and never was there so large a number of great and cultured and eminently virtuous and dispassionate minds who doubt or disbelieve the existence of a personal Deity. Whither are these facts pointing?"

The author thus explains the origin of his work:

"This book was at first designed only as a brief essay, as a private discussion with a friend, and it originated as follows: Conversing with Prof. B., of —— Theological Seminary, I asserted that the orthodox do not understand their opponents, that in the present state of philosophy Evolution can be rigidly maintained and triumphantly vindicated against all the assaults of Theism, and that the latter will have to adopt an entirely new method of defense and attack; and, as the professor disputed this, I promised to prove it in a short article, which now turns out to be a book. The object, therefore, of this volume is complex—first, to show to the orthodox that they stand on slippery places, that their philosophy and logic can afford them no legitimate aid and comfort; second, to show to the quasi-evolutionists that there is no medium between atheism, or non-theism, and the rejection of their own principles of science and philosophy; third, to show to the thorough naturalistic evolutionists that there is at least one man among the orthodox who thoroughly understands them—knows them better even than they know themselves—and who grants them all their principles, better expounded, and admits their legitimate consequences; and, fourth, that therefore the author must accept not only these principles, but also these consequences, unless he can furnish a new philosophy which shall use these acknowledged principles in combination with others, and thus attain other, or, rather, higher results. This the author believes to be possible, and that he is called to attempt it."

In conclusion, Mr. Gill says:

"We by no means consider the doctrine of Evolution, even in the most advanced philosophical state in which it has been presented, to be an all-comprehending philosophical ultimatum. We hold that it is just in its conclusions from its premises, and that its premises are indisputable. But there are broader and profounder truths yet undeveloped, which are partially and falsely discerned, and ignored or rejected; truths which, when fully expounded in their legitimate connections, will show that Evolution, instead of being the ultimate philosophy of the universe as it now appears, is infinitely subordinate; and these truths will introduce and demonstrate an infinitely sublimer theory, which will comprise Evolution as a vast temple comprises each of its most miniature figures, or as the material universe comprises each of its countless atoms.

"The theory of Evolution contains a body of facts, of deductions, of inductions, and of generalizations, so irrefragably true that, though they may be subsequently covered by further discoveries of facts and by deductions and inferences and broader generalizations, they cannot be overthrown; or, in other words, they may be absorbed, but cannot be refuted. We propose to cover, and absorb them. . . .

"The absolute unity of the known universe is no longer to be questioned, and as now conceived it precludes a personal Deity and our personal immortality. Now the great problem is: Can we expound this unity so as to prove a personal Deity and our personal immortality? With emphasis I answer—YES."

ANIMAL MECHANISM. A Treatise on Terrestrial and Aërial Locomotion. By E. J. MAREY, Professor of the College of France. Profusely illustrated. 283 pages. Price $1.75. D. Appleton & Co. No. XI. International Scientific Series.

THE author of the present work, it is well known, stands at the head of those physiologists who have investigated the mechanism of animal dynamics; indeed, we may almost say that he has made the subject his own. By the originality of his conceptions, the ingenuity of his constructions, the skill of his analysis, and the perseverance of his investigations, he has surpassed all others in the power of unraveling the complex and intricate movements of animated beings. We last month gave an exemplification of his method in the case of human locomotion, and in the present number of the MONTHLY we continue the

subject by briefly showing his mode of studying the various paces of the horse. The volume deals systematically and thoroughly with this whole subject, and is full of novelty and curious interest. Prof. Marey's elucidation of the mechanism of flight in birds and insects is one of the most exquisite pieces of experimental investigation that modern science affords. The fertility of his devices, by which the varied results are brought out in all their exactness to the eye, by the graphic method of illustration, is a source of constant surprise to the reader. He makes pictures of all his facts and laws. Of course the value of such investigations stands upon their own scientific merits, but they have a peculiar attractiveness as connected with the phenomena of life in which we are all concerned. Yet there can be no greater mistake than to suppose that such researches are destitute of practical utility. Upon this point Prof. Marey has the following excellent remarks in his introduction:

"The comparison of animals with machines is not only legitimate, it is also extremely useful from different points of view. It furnishes a valuable means of making the mechanical phenomena which occur in living beings understood, by placing them beside the similar but less generally known phenomena which are evident in the action of ordinary machines. In the course of this book, we shall frequently borrow from pure mechanics the synthetical demonstrations of the phenomena of animal life. The mechanician, in his turn, may derive useful notions from the study of Nature, which will often show him how the most complicated problems may be solved with admirable simplicity.

"It is easy to demonstrate the importance of such a subject as locomotion, which, under its different forms, terrestrial, aquatic, and aërial, has constantly excited interest. Whether man has endeavored to utilize to the utmost his own motive power, and that of the animals; whether he has sought to extend his domain, to open a way for himself in the seas, or rise into the air, it is always from Nature that he has drawn his inspirations. We may hope that a deeper knowledge of the different modes of animal locomotion will be a point of departure for fresh investigations, whence further progress will result.

"Every scientific research has a powerful attraction in itself; the hope of reaching truth suffices to sustain those who pursue it, through all their efforts; the contemplation of the laws of Nature has been a great and noble source of enjoyment to those who have discovered them. But to humanity, science is only the means, progress is the aim. If we can show that a study may lead to some useful application, we may induce many to pursue it, who would otherwise merely follow it from afar, with the interest of curiosity only. Without pretending to recapitulate here all that has been gained by the study of Nature, we shall endeavor to set forth what may be gained by studying it still further, and with more care.

"If we knew under what conditions the maximum of speed, force, or labor, which the living being can furnish, may be obtained, it would put an end to much discussion, and a great deal of conjecture, which is to be regretted. A generation of men would not be condemned to certain military exercises which will be hereafter rejected as useless and ridiculous. One country would not crush its soldiers under an enormous load, while another considers that the best plan is to give them nothing to carry. We should know exactly at what pace an animal does the best service, whether he be required for speed, or for drawing loads; and we should know what are the conditions of draught best adapted to the utilization of the strength of animals.

"It is in this sense that progress is being made; but, if we complain with reason of its slow advance, we must only blame our imperfect notion of the mechanism of locomotion. Let this study be perfected, and then useful applications of it will soon ensue.

"Man has been manifestly inspired by Nature in the construction of the machinery of navigation. If the hull of the ship is, as it has been justly described, formed on the model of the aquatic fowl, if the sail has been copied from the wing of the swan inflated by the wind, and the oar from its webbed foot as it strikes the water, these are but a small part of Nature's loans to art. More than two hundred years ago,

Borelly, studying the stability and displacement of fish, traced the plan of a diving-ship constructed upon the same principle as the formidable *monitors* which made their appearance in the recent American war.

"Aërial locomotion has always excited the strongest curiosity among mankind. How frequently has the question been raised, whether man must always continue to envy the bird and the insect their wings; whether he, too, may not one day travel through the air, as he now sails across the ocean! Authorities in science have declared at different periods, as the result of lengthy calculations, that this is a chimerical dream; but how many inventions have we seen realized which have also been pronounced impossible! The truth is, that all intervention by mathematics is premature, so long as the study of Nature and experiment have not furnished the precise data which alone can serve as a sound starting-point for calculations of this kind."

THE MAINTENANCE OF HEALTH. By J. MILNER FOTHERGILL, M. D. London: Smith, Elder & Co. New York: G. P. Putnam's Sons. 399 pp. 8vo. Price, $5.00.

THIS is a useful work on hygiene, and, as all intelligent hygienic action must be based upon some knowledge of the human subject, it opens with a description, in outline, of the composition of the body, of its various organs, the functions they perform, and the relations of food, exercise, and sleep. Then follows a consideration, in the natural order, of youth, maturity, and old age, with the dangers incident to each, and the precautions necessary.

In treating of the first stage, allusion is made to a danger little known and less heeded by people in general: this is, the effect upon children of violent outbursts of anger in parents and nurses. The young wife, by yielding to anger under the trials of her newly-assumed position, may doom her unborn babe to an imbecile existence. "The majority of imbeciles are first-born children, and their pitiful condition is the consequence of the mental perturbations during the term of pregnancy." Again: "In sucklings, too, mental disturbance in the mother or wet-nurse will commonly produce indigestion and diarrhœa in the baby." Nor does the danger end with infancy. Nearly every one has observed the deplorable influence which capricious paternal anger exercises upon children, some being made gloomy and morose thereby, others stubborn and revengeful. In connection with children advanced beyond the period of infancy, the author deplores the aversion, which they at the present day display, to eating fat, and recommends that parents should persistently endeavor to counteract it. He says: "Fat is most necessary to the proper growth of tissues, and, such being the case, is still more necessary to children." Without it, children grow up lean and spare.

The consideration of the causes of diseases in maturity is worthy of special attention. One of the most subtile of these causes, because little thought of, is the decay of the teeth. This is said to be on the increase, and is mainly attributed to excessive consumption of sugar, and the use of dentifrices. "Many dentifrices contain an acid which, by constantly eating away a thin surface of the enamel, keeps the teeth brilliantly white, but in time leads to their utter destruction."

Certain silly young ladies, who resort to the drinking of vinegar or the eating of raw rice, to avoid growing fat and florid, will be edified to learn that the amount of vinegar which will make them thin will destroy their digestive powers, and that a similar quantity of rice will produce habitual constipation, and prevent the assimilation of food.

In advanced life, many persons suffer much from inability to sleep. Moderate exercise during the day, and, at night, beds warmed before retiring, are recommended as the best remedies. In obstinate cases, a little alcoholic stimulant, mixed with warm water, may be taken to advantage just after entering bed. An important chapter is devoted to food and clothes, and another to stimulants and tobacco. The recent classification of alcohol as a food is adopted, and its use in small quantities considered harmless; in certain cases beneficial. Tobacco is also considered harmless in moderate quantities.

The chapter on mental strain, overwork, and tension, deserves a careful pe-

rusal. Men unfamiliar with the symptoms of an approaching breakdown of their mental powers, frequently work on blindly until comes the fall from which no power can lift them. Sleeplessness is one of the most significant warnings, and should never pass unheeded. In this connection, the author's remarks on the use of chloral hydrate, as an agent for promoting sleep, serve as a timely warning against that deadly remedy. Its action on the nerve-centres is destructive, and it produces a permanent condition of brain-bloodlessness fatal to mental vigor. Hygiene is the subject of an able discussion. The book will, unquestionably, prove of great value to those who read it carefully. It is not, however, intended as a family prescription-book, but as a safeguard against disease. In every case of actual sickness, it advises that the family physician be sent for.

CAVE-HUNTING: RESEARCHES ON THE EVIDENCE OF CAVES RESPECTING THE EARLY INHABITANTS OF EUROPE. By W. BOYD DAWKINS, M. A., F. R. S., etc. London: Macmillan & Co. 455 pp. 8vo. Price, $7.00.

THE prefatorial remarks of the author announce that this book is a faint outline of a new and vast field of research, intended to give prominence to the more important points, rather than a finished and detailed history of cave-exploration.

Caves have in all ages, and in all countries, been regarded with feelings of superstitious veneration; here, as the dwelling-places of the sibyls and nymphs, there, as the shrines of Pan, Bacchus, Pluto, the seat of the oracles of Delphi and Mount Cytheron, and in the far East they were connected with the mysterious worship of Mithras. These feelings long secured them from intrusion and exploration. At length, in the sixteenth and seventeenth centuries, they were thrown open for examination by the desire which then arose in Germany to possess the "*cour fossile*," or "unicorn's horn," a supposed infallible specific for the cure of many diseases. The "unicorn's horn" was to be found in the caves, and the search for it revealed the remains of lions, hyenas, elephants, and many other tropical or strange animals. At first these remains were supposed to have been washed thither from the tropics by the Deluge. Then the truth began to dawn that the animals lived in the surrounding country, and that the bones of such as were not cave-haunting were dragged into the caves by such as were. This truth was first enunciated by Rosenmüller in 1804. Between 1825 and 1841, an Englishman, the Rev. J. McEnery, discovered in Kent's Hole, near Torquay, the first "flint implements" ever observed, in a cave along with the bones of extinct animals, and he suggested that they proved the existence of man at the same time with those animals. But he died in 1841, leaving his suggestion scornfully repudiated by the scientific world; although, in 1840, Mr. Godwin Austin, by independent researches, verified its truth. It was not until after 1859 that the significance of this discovery came to be generally perceived and admitted. It, of course, immediately revolutionized the prevailing notions of the antiquity of man, while the previously-accepted theory of Rosenmüller unmistakably indicated the occurrence of remarkable geographical and climatal changes over the continent of Europe. The work before us traces the rise and progress of cave-exploration; considers the physical history of caves, that is, their formation, whether by sea or volcanic action; enumerates the most remarkable caves, with the objects they have yielded; treats of the character of the early inhabitants of Europe, and of the fauna of the same period, as indicated by the remains discovered; and, finally, of the climatal and geographical changes that have occurred since those deposits were made. The style is clear and vigorous, and the text is interspersed with numerous illustrations. The work will commend itself to all who have a desire to know something of what humanity was in that hazy period which stretches backward of the earliest records.

LECTURE NOTES ON QUALITATIVE ANALYSIS. By HENRY B. HILL, A. M. (Assistant Professor of Chemistry in Harvard College). New York: G. P. Putnam's Sons. 54 pp., 12mo. Price, 75 cts.

THIS little book is designed for the use of the chemical student. Explanatory of its object, the author says, in his preface, that, during lectures, the student being

under the necessity of taking notes, is often prevented from seeing what takes place on the lecture-table. The book is intended to give concisely the facts essential to intelligent work in the laboratory, that the student may have more leisure for observation in the lecture-room. The work shows the divisions of the bases and the acids into groups, as well as the means of detecting them; also directions for the examination of specimens, the reactions of various substances under different circumstances, and the method of treating them with water and with acids.

DEUTSCHE RUNDSCHAU. Herausgegaben von JULIUS RODENBERG. Monthly. $10 per annum.

THIS is the first number of a Review, intended to occupy, in German periodical literature, about the same rank that is held by the *Revue des Deux Mondes* in the periodical literature of France. Like its French prototype, it will contain novelettes and continued stories, historical sketches, political articles, scientific essays, poems, etc., together with book reviews, criticisms of music and the drama, and political notes. The scientific article in the present number is entitled "Botanical Problems," and is written by Prof. Ferd. Cohn, of Breslau. Stechert & Wolff, 4 Bond Street, New York, receive subscriptions for the *Deutsche Rundschau* in the United States.

PUBLICATIONS RECEIVED.

Lecture Notes on Quantitative Analysis (Hill). New York: Putnam's Sons. Pp. 64. Price, 75 cents.

Operation for Cataract (Jeffries). Pp. 15.

Insanity and Disease (Tourtellot). Pp, 15.

Catalogue of Plants (Wheeler's Expedition, 1871–'72–'73).

Ornithological Specimens (Wheeler's Expedition, 1871–'72–'73).

Archives of Dermatology (Quarterly). Putnam's Sons. Pp. 96. Three dollars per annum.

American Journal of Insanity (Quarterly). Utica, N. Y.: State Lunatic Asylum. Five dollars per annum.

MISCELLANY.

Does the Earth rotate at a Uniform Rate?—In the September number of *Silliman's Journal*, we find a remarkable paper by Prof. Newcomb, of the Naval Observatory, Washington, to the conclusions of which we wish to call the attention of our readers.

Prof. Newcomb, who has for some time been engaged on the most difficult problem of celestial mechanics—the "Theory of the Moon's Motion"—published, in 1870, a paper referring to some of the difficulties in this theory. He has treated the lunar theory in quite an original and exhaustive manner, and, in the course of his investigations, arrived at the fact that there were certain outstanding differences between theory and observation which had not yet been accounted for by the gravitation of the known bodies of the solar system. Prof. Newcomb suggested that there were only three possible explanations of the discrepancy: 1. The mathematical analysis was not sufficiently extended; 2. The motion of the moon was affected by some force different from gravitation; 3. The time of the earth's rotation on its axis was not constant.

The second hypothesis Prof. Newcomb showed was not at all probable, since the effects of a force other than gravitation would produce variations of a different kind from the ones actually noticed: the first hypothesis Prof. Newcomb has, since 1870, been engaged in testing, and his researches have convinced him that analysis has taken cognizance of every important inequality in the moon's motion. This makes it necessary to examine rigorously the third hypothesis, viz., that the earth's time of rotation on its axis is not strictly uniform.

This explanation is, at first sight, somewhat startling, since the absolute uniformity of the sidereal day has long been supposed certain. Prof. Newcomb's researches in 1870 led him, however, to the conclusion that the earth had been rotating somewhat slower than the average rate for ten or twenty years previous to 1860; that about 1860 the rotation was accelerated, so that there was a gain of *at least* a second per annum till about 1872.

This hypothesis would, we must re-

member, account for the inequalities in the moon's motion, but it rested on no independent basis. Since that time, Prof. Newcomb has devised a method of testing this question by totally different means, viz., by an examination of the eclipses of Jupiter's first satellite; and this test has been applied by Mr. Glasenapp, an astronomer of Pulkova. Mr. Glasenapp's researches indicate with great certainty that the earth's rotation is not strictly uniform, and that Prof. Newcomb's hypothesis is sustained. The accurate determination of the amount by which the earth is fast or slow is yet to be reached, but we must accept two important facts as probable: 1. That the earth's rotation time is not strictly constant. 2. That the inequalities in the moon's motion are largely, if not wholly, due to this.

Growth and Reproduction of the Antlers of the Deer.—John Dean Caton, whose observations on the natural history of the American *Cervidæ* are familiar to the readers of Mr. Darwin's writings, contributes to the *American Naturalist* for June an important paper on the "Structure and Casting of the Antlers of Deer." He shows, in the first place, the substantial identity of structure between the antlers and the ordinary bones; in fact, the antlers are *external* bones, of very rapid growth, which mature speedily, die, and are soon thrown off; while all other bones are very slow of growth, and persist through life.

The process of growth is as follows: The old antler having fallen off, the blood-vessels of the periosteum at its butt are ruptured, producing a copious flow of blood. Next, the periosteum grows over the cavity in the top of the *pedicel*, or process of the skull on which the antler stood. On the approach of spring, this covering becomes inflamed, resembling a blood-blister. It rises up rapidly, new systems of blood-vessels forming in it, till its height is twice its diameter; then an osseous deposit is commenced at the circumference of the top of the pedicel. As this deposit rises it thickens very slowly, the upper extremity presenting a thin, serrated edge. Blood-vessels from the periosteum traverse this tissue, supplying it with nourishment. This is the source of supply from without; but there are internal sources also, viz., arteries passing up through the pedicel, and answering to the medullary arteries of long bones.

At the extremities, first, the deposit of earthy salts goes on till this fills up the canals leading from the periosteum into the bony mass, so that the circulation through them is obstructed; and this process goes on till all communication between the internal and the external blood-vessels is severed. The animal is now prompted, by some natural impulse, to rub off this outer covering, while it is gorged with blood. The cavities in the branches and the upper portion of the beam soon become hardened throughout, and the solid wall in the lower part much thickened. Before the central section has become solid, the nutrient vessels are obstructed below, and the deposit of bony particles arrested, while yet the larger portions of the antler are more or less porous. This makes the antler lighter, without seriously diminishing its strength, for its walls are braced within, in every imaginable direction, by thin plates of bone.

In the mean time, the lower extremity, too, becomes more and more compact, and the pedicel, which, during the active growth of the antler, was open and porous, commences a new deposit of laminæ in its cavities. But now, all sources of nutriment having been cut off, the antler dies, and is removed by a singular process. One of the systems of blood-vessels which supply nutriment to the growing antler commences active operations to undermine it. The absorbents of these blood-vessels attack the point of junction between the antler and the pedicel. They do not carry away the surface of the bone evenly, so as to make it smooth, but, as it were, they remove alternate particles, till the union, which before was so firm that no force could break it at the point of juncture, has become so weakened that the antler is detached by some slight violence.

A Remarkable South American Valley.—According to *Iron*, the upper valley of the Rio Madeira, one of the chief tributaries of the Amazons, rivals California and Australia in mineral wealth. This valley, which contains about 400,000 square miles, is mar-

velously rich in every South American product of value. Its eastern and central parts, the Bolivian provinces of Cordillera, Chiquitos, and Beni, were first settled by the Jesuits, who penetrated northward from their settlements in the valley of the Rio de la Plata, and organized numerous "reductions" of the native tribes, and founded many prosperous towns. These, however, were always either on the banks of navigable streams, or within easy reach of them. In the extreme eastern part of the Madeira Valley is the Brazilian province of Matto Grosso, abounding in valuable agricultural products, and gold and diamond washings. Owing to its inaccessibility, it is very thinly populated, but no doubt, in the future, will be one of the most prosperous states of the Brazilian Empire. At present, it is one of the most unprotected frontiers of that country, being almost at the mercy of the states of the La Plata Valley in case of war.

Ascending the upper central and western rivers of the Madeira Valley, we come to the richest of all the slopes of the Andes, well populated by the Spanish race, mixed with Quichua and Aymara Indians, the Indian element being probably the best on the American Continent. The Bolivian part of the valley contains about 2,500,000 people, the Indian blood slightly predominating. At the date of Bolivian independence, 1825, the population was under 1,000,000. The country in which they live is, without exception, the richest on the globe, in every thing that Nature gives to man. Its mineral wealth cannot be matched within an equal area on the Western Continent. The number of silver-mines opened there during Spanish rule might appear fabulous, were they not registered in the archives of the state: they exceed 10,000! From the banks of the little streams which feed the Beni branch of the Madeira, gold may be washed almost anywhere. In fact, the whole slope of the Andes, in an immense sweep of 1,000 miles, extending from Cuzco to Matto Grosso, is a vast gold-placer.

A Rare Species of Rabbit.—In Prof. Hayden's "Report of the Geological Survey of the Territories" for 1872, Mr. C. H. Merriam describes a very rare species of rabbit (*Lepus Bairdii*) inhabiting the pine-regions about the head-waters of the Wind and Yellowstone Rivers, in Wyoming. Mr. Merriam secured five specimens of this animal, which, with the exception of one placed in the Smithsonian collection by Prof. Hayden, in 1860, are the first individuals of the species that have been brought before the scientific world. One very curious fact relating to Baird's rabbit is, that all the males have teats, and take part in suckling the young! Four out of the five specimens were adult males, and they all had large teats full of milk; and the hair around the nipple was wet, and stuck to it, showing that, when taken, they had just been engaged in nursing their young. As no females were found, Mr. Merriam thought this might be an hermaphrodite form; so he and Dr. Josiah Curtis dissected a large male, which was found to contain the usual male genital organs, but no uterus, ovaries, or other female organs. Another old male was dissected, with the same result.

Steel Bars for Bells.—An item has long been on its travels both in England and this country, announcing steel bars as a cheap and efficient substitute for bells in churches, factories, etc. To numerous letters of inquiry on the subject, we have been obliged to reply that we knew nothing of the kind either here or abroad. The London *Builder*, having been similarly questioned, has lately taken the trouble to examine the matter, and the following is the only foundation for the statement it has been able to discover:

On the 28th of July, 1873, a provisional specification only was granted by the English Patent-Office to Ferdinand Rahles and James Dixon Mackenzie, for new or improved bells, or bar-bells and apparatus connected therewith. This invention consists of sounding instruments made from bars of steel, or other metal compositions, of a straight or curved form, producing musical notes or sounds. These bars are made of any suitable weight or dimensions, according to the power of sound desired. They are intended to be a substitute for ordinary cast bells, for use in churches or other places, and are suspended and carried in or on frames perpendicularly or otherwise, the sounds being produced from them by con-

cussion with mallets or other mechanical contrivances worked either by manual or other mechanical agency.

Each bar is struck by a mallet or mallets, and motion is communicated to the arms of the mallets by cords or other suitable attachments to the outer end of the arms, and passing down the tower or other place where the bars are fitted. The inventors of the above not having perfected the patent, any one is now at liberty to carry out the design.

The Transmutation of Species.—A friend in Hamilton, N. Y., kindly sends us the following extract, translated from the German of Carus Sterne; the passage occurs in the course of an interesting essay by that writer on "The Radish:" "The more strict among modern botanists," says Sterne, "refuse to place the charlock (*Hederich*) in the same species with the radish. In general character, there is a considerable resemblance between the two; but this proves little, since most specimens of the *Crucifera* family show a strong habitual resemblance. In the fruit, which in this family furnishes almost the only distinguishing feature, a great difference exists. The charlock bears fruit from one and a half to two inches long, thin, necklace-like, with a decided beak, separating crosswise, at maturity, into joints, each joint containing a shining seed. The radish, on the contrary, bears a plump, coniform pod, almost without a beak; and, at maturity, it splits lengthwise. The seeds are not shining, but wrinkled. So great is this difference, that many modern botanists have departed from Linnæus's classification of these plants as two varieties of the same species—*Raphanus raphanistrum* and *R. sativus*—and have made of the former a separate species, *Raphanistrum*.

"But two summers ago, Prof. H. Hoffmann discovered that Linnæus was right. For four years he had cultivated charlock in the Botanic Gardens at Giessen, and at last had the joy of finding, amid many transition forms, genuine radish-fruit, upon two charlock-plants. As hybridization with radish was out of the question, this was held to be a demonstration of the specific identity of these two plants. This is a highly-important and instructive discovery: it is a sort of 'leap' which, morphologically considered, seems greater perhaps than that from man to ape.

"Those," continues the author, "who wish to know nothing of the transmutation of species, but who hold that all things have continued from eternity as they were created, will conclude that the devil himself has here stuck a pair of radish-pods in Prof. Hoffmann's charlocks, simply to lead men astray. Should the observation be verified (of which we have no doubt), and if we have not here to deal merely with a mixture of pollens, as in the supposed transformation of *Ægilops* into wheat, then will the radish become one of the strongest arguments for the Darwinian theory."

The Corrosion of Glass.—A correspondent sends the following on the corrosion of glass, by what would otherwise be considered a bland and harmless liquid:

"My daughters sometimes make a mantel ornament by half filling a glass tumbler with water, placing a little cotton on the water, and then laying some grains of wheat, oats, or flax-seed on the cotton. A small field of grain is soon the result; but invariably the glass is corroded in such a way as to look blurred and dim. In one or two cases, a bouquet of flowers cut from the stems in the yard, and placed in a glass tumbler, and accidentally left standing a few days, produced the same effect as the growing grain. After spoiling quite a number of glasses in this way—some of fine cut glass—the practice was abandoned as unprofitable in general. In one of the *corroded* tumblers there is now growing a fine patch of wheat. Your article on the action of mucilage brought this matter up in conversation. Whether others have noticed this fact is unknown to me; and, if not, this may be an item of news to them."

A Human Automaton.—The following particulars with regard to the case of the French sergeant, quoted in Prof. Huxley's Belfast letter, we find in the *Lancet*. During the late war between France and Germany, two and a half inches of the left parietal bone of his skull was carried off by a bullet, laying bare the brain on that side. The resulting paralysis of the members of

the right side of the body having yielded to treatment, and the wound in the skull having commenced to heal, the man began to resume his usual occupation of a singer in *cafés*. Soon, however, he was seized with nervous symptoms of an extraordinary nature, lasting from twenty-four to forty-eight hours, and he returned to the hospital. When in his fit, he is totally insensible to pain, but his will may be influenced by contact with exterior objects. When set upon his feet he marches on quite steadily, with fixed eyes, but utters no word, nor knows what is going on about him. If he meets with an obstacle in his way, he tries to make out what it is by feeling, and then attempts to get out of its way. If a pen be put in his hand he will fumble about for ink and paper, and, if he gets these, will write a very sensible business letter. Give him cigarette-paper, and he will take out his tobacco-pouch and make a cigarette, and light it with a match from his own box. If a by-stander extinguish the match, he will strike another; and so on till his supply is exhausted. But, if a lighted match be put into his hand, he will not use it, and will let it burn between his fingers. No matter what his tobacco-pouch is filled with, he will roll his cigarette all the same, and smoke it. When the fit is past, he has no recollection of what has been said or done.

Cremation among North American Indians.—Dr. John L. Le Conte read a paper at the Hartford meeting of the American Association, giving an account of a ceremonial of cremation among the Cocopa Indians of California, of which he was an eye-witness. A shallow ditch was dug, in which logs of the mesquite, a hard, dense wood which makes a very hot fire, with but little flame or smoke, were laid. The body was placed on the logs, with some smaller fagots piled upon it, and a few of the personal effects of the deceased were also added. Fire was then applied to the pile. At this point the doctor was about to retire, when one of the Indians told him to remain, as there was yet something to be seen. An old man then advanced from the assemblage with a long, pointed stick in his hand. With this he removed the eyes, holding them successively on the point of the stick in the direction of the sun, repeating at the same time words which were represented as being a prayer for the soul of the deceased. After this more fagots were heaped on the fire, which was kept up for three or four hours longer. When the fire has gone out, it is the custom to gather the fragments of bone and put them in a terra-cotta vase, which is kept under the care of the family. Dr. Le Conte was unable to say whether the custom of burning the dead was a general one or not, among this or other California tribes of Indians, but thought it desirable to gather up and put on record whatever evidence there might be on so interesting a subject, before the total disappearance of these people put the settlement of the question beyond our reach.

House-heating in Sweden.—A traveler in Sweden contributes to one of the newspapers an account of the very economical mode of house-warming adopted in that country. The *kakelung*, or Swedish stove, is a great oven of masonry covered with porcelain plates, having usually five flues, through which the gases of combustion must pass up and down, a distance of thirty to fifty, or even sixty feet, before escaping into the air. The general principle of their operation is to provide enough material to absorb all the heat from the fire; to conduct the gases through these long flues till their temperature has fallen to a point that no longer gives off heat. The quantity of the material in the kakelung is so great that the temperature from one firing will not raise the temperature of any part so much that the hands cannot be held upon the outside. Two hours after a fire is made, and after the wood-fuel has burned up, and the flue been closed, the kakelung begins to get warm on the outside, the light porcelain plates give off their moderate warmth to the atmosphere in the room, and ten hours later there will not be much difference in the temperature of the stove or of the room. A kakelung, instead of being an unsightly obstruction, is an ornamental piece of furniture. A door opens into it in front, where, in a kind of closet with iron shelves, food can be kept warm, or warmed. Baking can be done in the furnace for hours after the fire has been burned out.

How Suctorial Insects feed.—It is commonly supposed that dipterous, or two-winged insects, never eat the pollen of plants, their mouths being destitute of mandibles, and fitted only with a tube, or proboscis, for sucking up juices. That this statement does not hold good for all insects belonging to this order, is shown from observations lately made by Alfred W. Bennett. This distinguished entomologist has found that at least insects of the family *Syrphidæ* (hoverer-flies) eat the pollen of plants. He has examined, under the microscope, the contents of the abdomen of two species of syrphidæ, which he found to be colored a bright orange, owing to the presence of enormous quantities of aster-pollen. That the grains of pollen are not accidentally taken up, but form an actual article of food, is proved by their being found in every stage of digestion, the fluid contents of the grains being apparently the nutritive substance, and the skins being ultimately excreted. During the last spring, Mr. Bennett captured *Eristalis tenax* (the drone-fly) on the flowers of the sloe. The abdomen of the insect was full of pollen-grains, belonging to at least three kinds of plants—sloe, dandelion, and probably fuchsia.

Oxidation retarded by Molecular Vibrations.—A paper was read, at the American Association meeting, on "Mechanical Vibration retarding Rust," by Prof. S. S. Haldeman. The iron track of a railroad is but little subject to oxidation, while iron rails piled alongside quickly rust. If traffic be suspended on a railroad for a day, and, in the mean time, a rain of some hours' duration fall on the rails, they soon show signs of rust. From these facts Prof. Haldeman argues that, in chemical combination, mechanical vibrations may interfere with the molecular arrangement of the elements. He would, however, have these casual observations submitted to the test of experiment. A discussion followed, in the course of which it was suggested that possibly the oil employed upon locomotives might be more or less spread in a thin film over rails in use, and thus prevent their oxidation. This view met with no favor. Prof. Van der Weyde was quite certain that the suggestion of Prof. Haldeman had reference to a fact in physics. Molecular vibrations do undoubtedly tend to prevent rust: a saw hung up unused would soon grow rusty, whereas if used it would keep bright; and the observation is universal with regard to mechanical tools.

The Metric System of Weights and Measures.—On the last day of the Hartford meeting of the American Association, President Barnard, of Columbia College, delivered an address on the "Metric System." He predicted that the metric system will become the sole system of weights and measures in use throughout civilized nations before the year 1900. In France, Holland, Belgium, Spain, Portugal, Italy, Switzerland, the German Empire—in fact, all Europe, except Scandinavian countries and England, and in all America, except the United States, the metric system has been adopted. Even in the Indian empire of Great Britain the metric system has been adopted, and that system has been legalized, though not yet adopted, in Great Britain and here. At the Vienna Metrological Congress, every delegate, though representing nearly every country on the civilized globe, voted for the metric system.

NOTES.

The American Society of Civil Engineers have appointed a committee to report on plans for—1. The best means of rapid passenger transit; and, 2. The best and cheapest method of delivering, storing, and distributing goods and freight in and about the city of New York. The society ask for suggestions from all civil engineers, and others who may be possessed of any information touching the subject of their investigations. The secretary of the society is G. Leverich, and his address is 63 William Street.

Last December a telegram was sent from New York to London, and an answer received in 30 minutes actual time. The distances traversed were as follows: from New York to Heart's Content, N. F., 1,300 miles; cable, 2,000; Valentia to London, 300 miles. Each of the telegrams, therefore, traveled 3,600 miles, and passed through the hands of 18 persons.

An international exhibition has positively been decided upon in China, and a com-

mittee formed at Shanghai for the purpose of organizing it, the English consul being its president. All charges of transport will be defrayed by the committee. The *Academy*, our authority for the above statement, does not say what part the Chinese Government are to take in this important enterprise.

In his address at the Breslau Congress of German Naturalists and Physicians, Virchow spoke of the miracles said to have been performed at the scenes of many of the recent Catholic pilgrimages. He had not, he said, visited Louise Lateau, the Belgian *stigmatiste*. An examination, he observed, would have led to no useful result, except under certain conditions laid down by himself, and rejected by the other side.

Dr. Adolf Meyer has collected in New Guinea 63 different specimens of animals belonging to the orders reptilia and batrachia, of which 34 are new to science. The predominant types are Australian.

In Prince William County, Virginia, according to the Monthly Report of the Department of Agriculture, wasps were last summer observed destroying the Colorado beetle very rapidly. From the same authority we learn that in Whiteside County, Illinois, a new beetle, undescribed, attacked the larvæ of the Colorado beetle, "thrusting it through the body with its beak and killing it instantly."

The operations of the Irish Peat Fuel Company, though prosecuted under the most unfavorable circumstances during the winter months, have given very satisfactory results. By a mixture of the lighter and heavier portions of the peat, a fuel has been obtained having a density about 15 per cent. that of coal. This peat-fuel is also full of gas, burns with a bright, hot flame, and produces a hard cinder, which remains red throughout until it is entirely consumed. The density of the fuel, it is thought, will render it suitable for smelting-purposes; and, if so, it would be possible to produce a superior quality of iron from the Irish ores, which are at present comparatively valueless, owing to the want of a suitable fuel to smelt them.

The construction of the Panama Railroad cost 81,000 human lives, destroyed by malaria; this death-rate is equal to one man per yard of the track.

During six hours of July 29th last, rain fell in Chowan County, North Carolina, to the depth of twelve inches.

At the request of Mr. A. W. Sheldon, general agent of the Prison Association of New York, the Commissioners of Charities and Correction have had a room set apart for a library in Blackwell's Island Penitentiary. The library-room is suitably fitted up for its destined use, and the Association has already made a liberal donation of books. We are requested to state that contributions of books, magazines, etc., for the above library will be received at the office of the Association, No. 19 Centre Street.

A Microscopical Society has recently been founded in Memphis, Tennessee. Its membership is already numerous, and its regular semi-monthly meetings are characterized by a large attendance of members, as also by an evident determination to forward the cause of microscopic research by hard, honest work. At the second October meeting of the society, A. F. Dodd read a paper on infusorial life, illustrated by drawings from life of a large number of specimens

La Nature vouches for the absolute correctness of the following figures, showing the consumption of tobacco in France in 1873: Smoking-tobacco, 40,000,000 lbs.; cigars, 7,716,976 lbs. (925,000,000 cigars); snuff, 16,536,375 lbs.; chewing-tobacco, 1,433,152 lbs.; "carotte," a sort of tobacco used (mostly in Brittany) for smoking, chewing, and snuffing, 992,182 lbs. Total, over 66,500,000 lbs. The total revenue derived by the state from this manufacture was last year 294,000,000 francs. Paris has 1,200 tobacconists' shops.

After the death of Boerhaave, the most celebrated physician of the eighteenth century, there was found among his books a volume sumptuously bound, in which were written down, he used to say, all the secrets of physic. All the pages were blank, except the frontispiece, on which he had written in his best hand this sentence: "Keep the head cool, the feet warm, and the bowels open."

The annual report of the treasurer of the French Association for the Advancement of Science shows that this, the youngest of the national scientific institutions, stands upon a sound financial basis. At the close of 1873 it had a funded capital of about 166,000 francs, yielding an income of over 9,000 francs. This income, together with the subscriptions of members, brought the total receipts of 1873 to about 30,000 francs. This money is judiciously expended in giving encouragement to original research.

Another Jesse Pomeroy has appeared in Chico, California. A boy in that town has developed an uncontrollable propensity for injuring with stones, clubs, etc., all the little children that he meets. He has been lodged in jail, and now threatens to kill a number of his companions as soon as he is released.

PROFESSOR JEFFRIES WYMAN.